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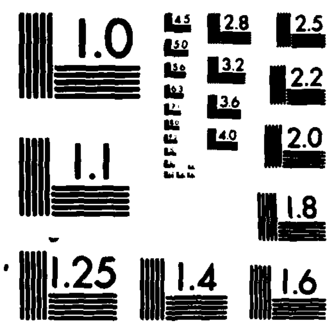
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**DNA 5288F**

# WARTIME RECONFIGURATION OF THE PUBLIC TELEPHONE NETWORK

The BDM Corporation
7915 Jones Branch Drive
McLean, Virginia 22102

11 April 1980

Final Report for Period 23 April 1979–11 April 1980

CONTRACT No. DNA 001-79-C-0288

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Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, D. C. 20305

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

# REPORT DOCUMENTATION PAGE

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19

| | |
|---|---|
| 1. REPORT NUMBER | 18 DNA 5288F |
| 2. GOVT ACCESSION NO. | AD-A089 721 |
| 3. RECIPIENT'S CATALOG NUMBER | |
| 4. TITLE (and Subtitle) | 6 WARTIME RECONFIGURATION OF THE PUBLIC TELEPHONE NETWORK. |
| 5. TYPE OF REPORT & PERIOD COVERED | 9 Final Report, ~~for Period~~ 23 Apr 79—11 Apr 80 |
| 6. PERFORMING ORG. REPORT NUMBER | 14 BDM/W-80-203-TR |
| 7. AUTHOR(s) | 10 Ralph Schmidt<br>John H. Cronin, Jr |
| 8. CONTRACT OR GRANT NUMBER(s) | 15 DNA 001-79-C-0288 |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | The BDM Corporation<br>7915 Jones Branch Drive<br>McLean, Virginia 22102 |
| 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS | Subtask 099QAXCC302-02 (16) |
| 11. CONTROLLING OFFICE NAME AND ADDRESS | Director<br>Defense Nuclear Agency<br>Washington, D.C. 20305 |
| 12. REPORT DATE | 11 11 Apr[redacted]80 12 82 |
| 13. NUMBER OF PAGES | 80 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) | 17 C302 |
| 15. SECURITY CLASS (of this report) | UNCLASSIFIED |
| 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE | |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This work sponsored by the Defense Nuclear Agency under RDT&E RMSS Code B363079464 099QAXCC30202 H2590D.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Switched Systems
Public Telephone Network
Electronic Switching System
Adaptive Logical Reconfiguration
Routing Algorithms
Critical Government Users
Defense Switched Network

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

→ This document presents the results of a preliminary investigation of the feasibility of adaptive reconfiguration as a means of using the surviving portions of the public telephone network in wartime. The effort assessed potential enhancement to survivable communications, perhaps in a nuclear degraded environment, by utilizing a wartime switching router. The major outputs of this effort are a system —

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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20. ABSTRACT (Continued)

description, a set of critical Federal users, routing algorithms, a bibliography, and conclusions concerning overall feasibility.

# PREFACE

This draft Final Report is presented to the Defense Nuclear Agency, Washington, D.C., 20305, as a deliverable under terms of contract number DNA001-79-C-0288. The document represents a three-month research effort by technical staff members of The BDM Corporation.

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## SECTION 1
## INTRODUCTION

### 1.1 PURPOSE

This document presents results of a first order investigation of the feasibility of adaptive reconfiguration as a means of using any surviving portions of the public telephone network (PTN) in wartime to provide critical military users with additional communications capabilities. The purpose of this study is to assess potential enhancement to survivable communications, perhaps in a nuclear degraded environment, by utilizing a wartime switching router for adaptive logical reconfiguration of the PTN. Logical reconfiguration, as opposed to physical reconfiguration, refers to the rerouting of critical calls by control and direction of special or wartime software. The reconfiguration is further described as adaptive to mean software would attempt to maintain full access and nonblocking for critical users even as degradation of the PTN increases and call traffic increases.

The major outputs of this effort include:

(1) routing/reconfiguration algorithms,

(2) identification of critical Federal users,

(3) conclusions concerning overall feasibility,

(4) system description, and

(5) bibliography.

The first three outputs are presented in Sections 2, 3, and 4 respectively, with supporting information in the Appendices. The public telephone system is described in Appendices D, E, and F. A set of references useful for further research can be found in Appendix G.

### 1.2 BACKGROUND

The Department of Defense (DOD) has several specialized and dedicated leased communications systems for the delivery of essential command and control information. This capability would be particularly critical during and immediately following a large-scale nuclear attack on

the United States. The ability of current DOD communications systems to assure survivable communications has been extensively studied.

Major elements of the DOD communications switched systems, such as the AUTODIN and AUTOVON, are located at or near high value targets. Previous study efforts have shown low probabilities of survival for these DOD switches in the event of a large-scale nuclear attack. By comparison, the PTN is highly dispersed geographically, and thus less dependent upon PTN assets near high value targets. In addition, the PTN is more than two orders of magnitude larger than the dedicated DOD switched systems. It is therefore reasonable to conjecture that after a nuclear attack on United States, a significant portion of the PTN will continue to be operational.

At issue is whether the immense size and the geographical dispersion of the PTN can be exploited for survivable communications for critical DOD users. That is, the local end offices, most likely elements of the PTN to survive, would need to be internetted (manual or automated) for long distance work since transmission system fractures would be widespread. In the last 25 years and perhaps longer, this approach to enhancing communications capability has surfaced and has been discussed at various times. However, continuing introduction of new technology (e.g., digital switches) into the PTN during the 1970's and 1980's makes this a particularly opportune time to investigate the contribution of the PTN to critical military user's communications. For it is the continuing conversion of the PTN from electromechanical analog switches to electronic digital switches that makes possible the implementation of adaptive routing schemes. The planned use of the Consultative Committee on International Telegraphy and Telephone (CCITT) Signaling System, which includes precedence fields, makes possible implementation of schemes requiring the ability to identify individual call criticality.

However, at the same time, efforts are underway to deregulate the telecommunications in the U.S. and the Department of Defense has expressed

concern 1/ that proposed legislation (rewrite of Communication Act of 1934) might weaken the technical integrity of the PTN by creating multiple, independent, non-standard private telecommunications systems which could not function as an entity under the stress of nuclear attack. Accordingly, analysis of the feasibility of adaptive routing is examined within the context of the larger issue of trends in the PTN. Reconstituted telephone communications might also contribute to a proposed nation-wide "Emergency Response Communications Program (ERCP)". The proposed ERCP has been studied under the continuing auspices of the (Federal) Interagency Committee on Search and Rescue. Still conceptual, the ERCP could be applicable across a wide range of emergencies from highway accidents through natural disasters and catastrophic events.

## 1.3 SCOPE OF RESEARCH

Certain bounds and constraints have been adopted to identify the breadth and depth of this feasibility investigation. First, this study is designed to proceed to a conclusion independent of any key information which AT&T or the U.S. Independent Telephone Association (USITA) could provide. Second, the alternative routing schemes for logical reconfiguration of the PTN will be characterized by key attributes. A third assumption is the independence of any particular threat scenario against the PTN assets or users; a massive nuclear attack against the United States is assumed.

A final consideration is that the major focus of this study effort is on the technical feasibility of using rerouting algorithms to reconstitute critical communications. Non-technical issues dealing with public policy and commercial sensitivities are presented as deemed significant.

## 1.4 FEASIBILITY METHODOLOGY

Feasibility can be decomposed into a number of critical components which are collected under convenient headings of technical

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1/ Letter from General Counsel of DOD of to Director of OMB, 1 August 1979. Letter from General Counsel of DOD to Chairman, Committee on Interstate and Foreign Commerce, House of Representatives, 3 July 1979.

feasibility and political acceptability, as depicted in Figure 1. In this study, major focus was on logical reconfiguration and technology assessment. Political issues were considered to some extent because they are interrelated with the technical issues.

Section 2 covers switching algorithms for logical reconfiguration and the technology advances which support implementation of these algorithms. Consistent with the focus of this effort, no system-level network analysis is performed nor is technical implementation risk assessed. For purposes of understanding the technical issues, much of the related analysis ignores any political issues.

From this determination of technical feasibility, the proper perspective for overall feasibility is gained by consideration of the political or public policy issues. Technical solutions to provide for reconfiguration of the PTN are useless without the acceptance of such political issues as the deregulation of the PTN and the Federal Government's authority to specify special access users to the PTN. The significance of political acceptability to overall feasibility is discussed and summarized in Section 4.

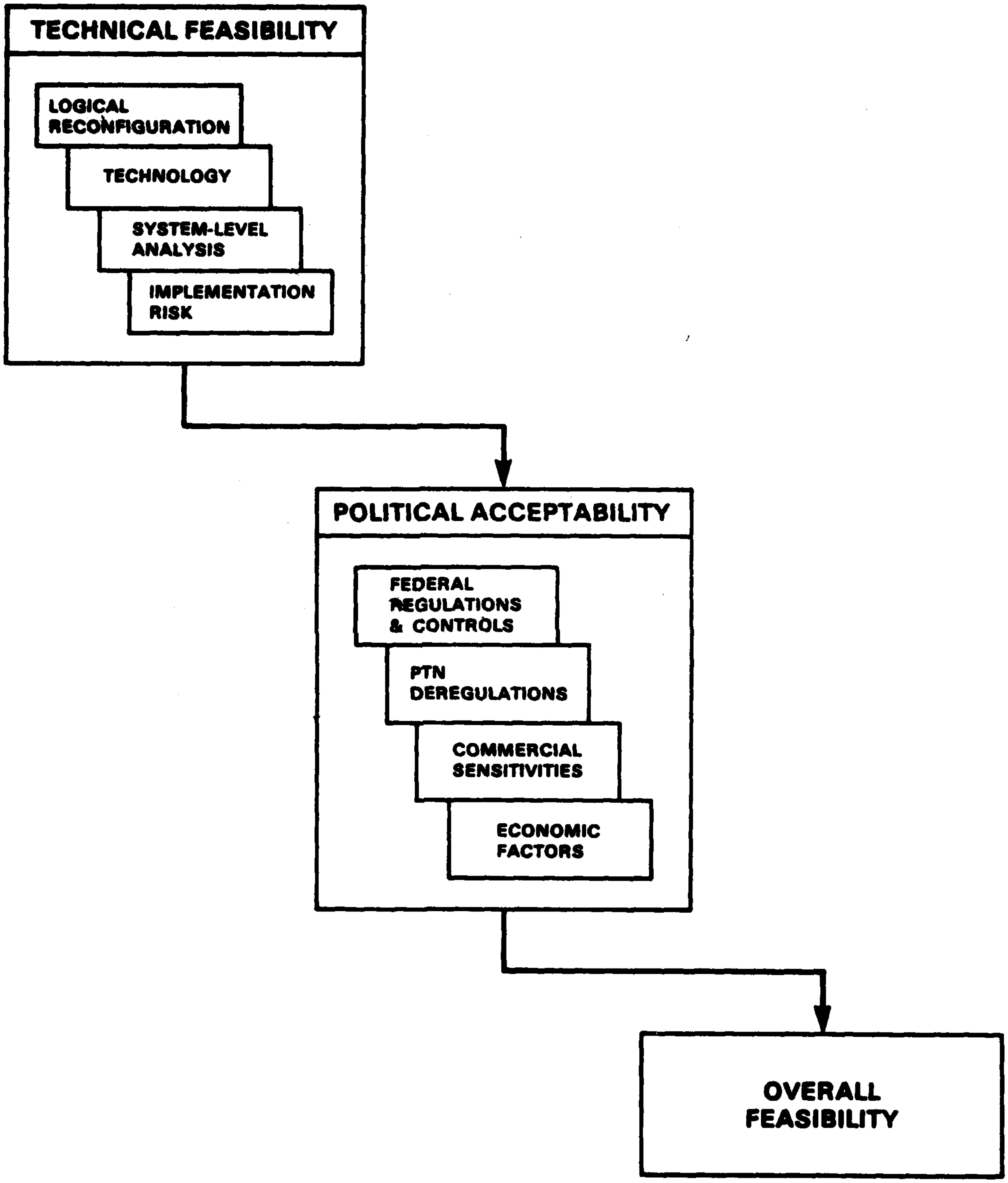


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Figure 1. Feasibility issues.

## SECTION 2
## ROUTING/RECONFIGURATION

### 2.1 OVERVIEW

The subject of routing and reconfiguration encompasses both physical and logical operations in a communications network. For purposes of the following discussion, all references made to routing and reconfiguration will mean logical unless specifically stated otherwise in the text.

The routing algorithms under study are real-time programs which adapt to two classes of changes: network topology and network traffic. As nodes and lines in the network fail and are repaired, algorithms reroute traffic accordingly. The algorithms also adapt to changes in the level and direction of traffic flow in the network. In adapting to these stimuli, the routing doctrine is attempting to maintain the best route to given destinations at all times.

Additionally, the algorithms under consideration are designed for a distributed non-hierarchical network. As discussed in Appendix D, the public telephone system is presently governed by a hierarchical structure. This structure could break down in a wartime situation if a number of the key network switches are made inoperable.

The objective of the algorithms presented here is to provide a method of maintaining critical communications in a dynamic network. Of the many routing and reconfiguration techniques available today, only those which appear to be reasonable based on future technology and government requirements are presented.

### 2.2 ROUTING ALGORITHMS

#### 2.2.1 Saturation Routing

Saturation routing means flooding of a network with messages which search for a particular subscriber's number without regard to that subscriber's location in the network. Saturation routing, often thought as inappropriate in a communications network, can be a useful routing scheme

with use of state-of-the-art design. The key technique employed in saturation routing requires each switch in the network to attempt connection when an incoming message is received. Advantages to this technique are as follows:

(1) Called subscriber searching is automatic and subscribers may retain their directory numbers wherever they move.

(2) Each switch maintains only a directory of its local subscribers.

(3) The routing will tend to favor the shortest and lightest loaded path through the network, avoiding local congestion.

(4) Subscriber search and route selections are performed together.

(5) Call routing is based on instantaneous network status and configuration at time of search, resulting in fast responding adaptive routing. Routing will adapt instantaneously to widespread destruction or deployment of additional switches.

(6) Resistance to failure and partial destruction is excellent since, even if only one possible path remains to connect two subscribers, that path will be found.

(7) Preemption of existing calls of lower precedence will provide an improved grade-of-service to each precedence level over that of lower levels.

(8) System control requirements are greatly reduced since the network is self-adjusting and no routing tables need to be maintained.

Saturation routing will result in some not so desirable effects, particularly with respect to network efficiency. Because the last available route is selected, even if it employs significantly more links then the most direct route, which is desirable for that call, it can now force the next call to select a longer alternate path, etc. (Reference (10) in Subsection G.2)

### 2.2.2 Minimum Delay Routing

In minimum delay routing the communications network consists of nodes called Interface Message Processors (IMP). Each IMP maintains a network delay table which is a matrix of delay estimates a message packet would encounter in reaching an IMP over each of its output lines. Figure 2 shows, for example, the network delay table for IMP 2, so that the delay from IMP 2 to IMP 5 using line 1 results in 5 units of delay. Every 2/3 second the IMP updates its network delay table, from which a minimum delay table is calculated. The values in the minimum delay table provide the smallest delay over all lines. Hence in Figure 2, IMP 2 to IMP 5 in the minimum delay table has a value of 4, resulting from line 3.

Continuing to consider IMP 2, note that all the neighbors of IMP 2 are also sending out their minimum delay tables every 2/3 second. IMP 2 will use these minimum delay tables to update its network delay table. A minimum delay table forwarded from neighbor i over communications line j is used to replace row j in IMP 2's network delay table. Then the value for destination i in IMP 2's minimum delay table is added to the new row j. This finishes the updating and a new minimum delay table is calculated by simply picking the minimum delay from each column. Additionally the minimum delay of an IMP to itself is set to zero. The communications line over which the minimum is achieved is recorded in a routing table. See Figure 2 for some examples.

Thus the IMP has an estimate of the total delay to each destination over the best path to that destination. The algorithm does not need to keep all the neighbors' tables stored; it is sufficient to keep the current overall minimum on each line. Then whenever a neighbor's table is received, a new minimum delay table is immediately calculated. Each IMP uses its current minimum delay table and routing table to forward message packets to other IMPs. In this manner, the algorithm minimizes delay along every link between IMPs. The ARPANET is an example of a communications network which successfully utilities this algorithm.

There are several drawbacks to this technique when applied to the public telephone system. The algorithm must accommodate a voice network.

NETWORK DELAY TABLE

DESTINATION (IMP)

| LINE | 1 | 2 | 3 | 4 | 5 | . . . | 64 |
|---|---|---|---|---|---|---|---|
| 1 | 14 | 6 | 7 | 12 | 5 | | 12 |
| 2 | 8 | 8 | 7 | 5 | 8 | | 18 |
| 3 | 6 | 7 | 6 | 8 | 4 | | 19 |

MINIMUM DELAY TABLE

DESTINATION (IMP)

| 1 | 2 | 3 | 4 | 5 | . . . | 64 |
|---|---|---|---|---|---|---|
| 6 | 0 | 6 | 5 | 4 | | 12 |

ROUTING TABLE

DESTINATION (IMP)

| 1 | 2 | 3 | 4 | 5 | . . . | 64 |
|---|---|---|---|---|---|---|
| 3 | 0 | 3 | 2 | 3 | | 1 |

01269/BOW

Figure 2. Delay tables for minimum delay routing.

Further, the routing algorithm was designed for a network with the same types of nodes and circuits, whereas the PTN has vastly differing switches. Minimum delay routing was also designed for a network of limited size, less than 100 nodes. The procedure to update the delay tables is too slow to handle a large and dynamic network such as the PTN or even a subset of the PTN. (Reference (2) in Subsection G.2)

A technique similar to the minimum delay routing procedure is described in an article by Robert G. Gallager, who suggests minimizing overall delay of all messages, instead of minimizing each packet's delay with no regard to other packet's delays. (Reference (9) in Subsection G.2) Here again, the major drawback is the time to propagate updates through the system.

2.2.3 Shortest Path with Hold Down

The shortest path algorithm is similar in operation to the minimum delay routing technique except that the criteria for information transmission between two switches concerns the number of links in a path rather than the minimum delay in a path. This algorithm operates on the principle that each link in the network carries a value calculated by length, speed, location, etc. Paths from one switch to another switch are selected by choosing the smallest cumulative value. When a line fails, the value for it is set to maximum and the routing algorithm will forward information accordingly through the network.

An additional feature may be added to this algorithm to facilitate the search and connect times. This feature, known as hold down, stipulates that once a path has been selected via the shortest path algorithm, that path is followed and no recalculations for shortest path are made until the next link on the path is found to have a maximum value. This reduces the number of times the path must be calculated and therefore reduces the processing time of the call.

The disadvantages as applied to the PTN are as outlined for the minimum delay algorithm. The propagation of information through the network may require too much time and resources when applied to the public telephone system. (Reference (6) in Subsection G.2)

### 2.2.4 Least Cost Routing

The DOD is presently developing concept plans for the merging of certain features of various DOD and commerical communications networks to achieve a survivable cost-effective communications system. The resulting CONUS Defense Switched Network (CDSN), as described in Appendix A, is planned to provide automatic "least cost routing" for PRIORITY and ROUTINE precedence users. Appropriate "automatic message accounting" is also planned to manage and control both long distance and local area calling.

## 2.3 APPLICABILITY TO PTN

Due to the inherent properties of the PTN, the routing techniques discussed above do not apply directly. For some algorithms the large size and complexity of the PTN pose problems of timely updating of the data base needed for rerouting decisions. The hierarchical nature of the PTN renders most algorithms ineffective as they are designed for distributed or decentralized networks. The algorithms also depend on digital processing techniques, which is only alleviated by the conversion of PTN's electromechanical switches to digital devices, such as the No.4 ESS.

Critical limitations are further imposed by political acceptability involving deregulation of the PTN and the decentralization connected with the hierarchical structure of the PTN. CDSN's least cost routing, although in the conceptual stage, is particularly promising as it is DOD-supported, thus obviating certain of the political issues. As the CDSN will utilize certain commerical systems including the PTN or perhaps a subnet of the PTN, least cost routing may as a minimum prove useful as a starting point both technically and politically.

## SECTION 3
## PRIORITY TELEPHONE USERS

### 3.1 PRIORITIES

In the chaotic conditions sure to attend a nuclear attack on the United States, literally thousands of Federal, State and other governmental or non-governmental users would necessarily compete for whatever available telephone capacity might still be available. Since not all these potential telephone users could be accommodated simultaneously, any rerouting plan and rerouting activity must incorporate unequivocal priorities established in advance. Thus, important early steps would be to identify highest priorities among Federal users and to specify the time periods for which their priorities apply. Similar procedures with State and local governments would then provide a complete list when merged with the prioritized Federal users. In this study effort, the key Federal users are identified by categories; actual prioritization should be undertaken by a government agency.

### 3.2 NON-DEFENSE KEY USERS

The Federal Emergency Management Agency (FEMA) is responsible for coordinating Federal emergency preparedness and mobilization activity. FEMA has listed various Federal and some non-Federal departments, agencies or other activities in categories to reflect the urgency of their continued operation under wartime conditions. The 38 highest precedence agencies are covered by Category A; this signifies that they have national level uninterruptable functions, such as those involving the trans-attack and immediate post-attack period of a general war. Moreover, each of these 38 agencies may, and do, designate some of their contiguous or distant subsidiary elements as falling within the Category A definition. Basically, Category A agencies are required to increase probability of their continued operation through competent staff elements at their regular peacetime headquarters, and at two additional geographic locations. Separate from the 38 national level agencies themselves, similar capabilities for continuity are needed for their subsidaries throughout the ten standard

Federal Regions of the United States. Regional Category A agencies must maintain primary management capability at their peacetime locations, and be able to establish a secondary management capability at one of the eight Federal Regional (emergency) Centers (identified in Appendix B). FEMA's Category A listing includes 38 Federal activities:

(1) 12 Federal Departments,*

(2) 18 Independent Agencies, and

(3) 8 Executive Offices

Appendix B contains the Category A list, plus some additions as explained in the Appendix.

### 3.3 KEY MILITARY USERS

Key or critical military telephone users are so numerous that any attempts at an exhaustive list would be inconclusive. Appendix C categorizes some 200 potential key users according to functions they would need to perform in the minutes and hours before, during and after a heavy nuclear attack on the United States.

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* Emergency roles of the new (thirteenth) Department, Education, are not yet clear.

## SECTION 4
## CONCLUSIONS

### 4.1 ANALYSIS OF ALTERNATIVES

The logical reconfiguration of the PTN by the use of routing algorithms is found to be technically feasible given time for the PTN to evolve and given acceptability of certain political issues. As the system description has shown, the incoming No.4 ESS is a significant factor relevant to implementation of any routing software. Other little known emergency techniques such as pinned-up circuits and storm-break plans would require in-depth research and development before any automated rerouting across toll areas is possible. Political issues concerning the telecommunications industry, for example the hierachical nature of the PTN, will have great impact on technical alternatives. That is, a technical solution would never be implemented if political issues are not resolved. Federal agencies such as FEMA, NTIA, and DOD (Assistant Secretary of Defense-$C^3I$) are all actively addressing such issues.

The conceptual CONUS Defense Switched Network (CDSN) with its least cost routing technique presents an alternative which warrants special attention. The CDSN is to provide an algorithm to be operational in peacetime for low precedence users. This would serve as a starting point from which other capabilities could evolve, such as routing capability for all critical users. In times of war, this least cost routing algorithm could be used to provide surviving circuits for high precedence users. As DOD plans for the CDSN to use a mix of communications networks, it implies some resolution to certain political issues. The use by the CDSN of PTN elements is an initial step in logical reconfiguration of the whole PTN. The CDSN with least cost routing appears the most viable alternative for reconfiguration of the PTN, and in consideration of the DOD support, perhaps the only currently viable alternative.

### 4.2 SUMMARY

There is little argument that technical solutions to allow better use of the surviving PTN become more attractive as that network slowly

converts from analog to digital switching. This brief report addresses only switching, and shows that it is feasible to construct coding and algorithems which can guarantee better connectivity between surviving subscribers among residual islands of the PTN. However, as this study has also shown, there are a number of other issues which have little to do with switching algorithms and which determines the usefulness of such a wartime capability.

A central question is the future of the PTN itself, if current trends toward Federal deregulation continue. As specialized carriers expand their market penetrations, they will, on the one hand, provide transmission paths to offset some of the hierarchical structure problems of the PTN. However, there is as yet no plan to insure the ability to internet this growing number of specialized carriers. Indeed, this has been a major concern expressed by DOD.

Technical means notwithstanding, these is little consensus as to the proper mix of public agencies which should be granted special access to the PTN during and after a nuclear attack on the United States. While techniques such as line-load control could routinely prevent excessive user demands from doing self-inflicted damage to the PTN, there is no agreed plan to implement such controls for wartime emergency switching. The formulation of such a plan may well transcend the authorities of any agency of the Federal Government.

The DOD-conceived CONUS Defense Switch Network (CDSN) concept is, among other things, an effort to eliminate the need for a separate AUTOVON system through use of the Defense Metropolitan Area Telephone Systems (DMATS), the General Services Administration Federal Telephone System (FTS) and commercial systems. It appears that the application of a "wartime" router should be studied first within the more managable context of the PTN as seen through the CDSN.

In summary, investigation has shown that non-technical issues cloud the question of wartime use of the PTN and that any further study of the utility of a wartime router should be conducted within the framework of the conceptual DSN.

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# APPENDIX A
# DEFENSE SWITCHED NETWORK (DSN)

## A.1 DSN CONCEPT

The DSN is a concept for the Continental U.S. (CONUS) which merges certain features of the worldwide Defense Communications System (DCS), the national, civil Federal Telephone System (FTS), individual military services base/enclave electronic switches, and the collective domestic and international commercial facilities/services, to eliminate costly separate (dedicated) systems and to achieve a requisite survivable communications system at affordable cost.

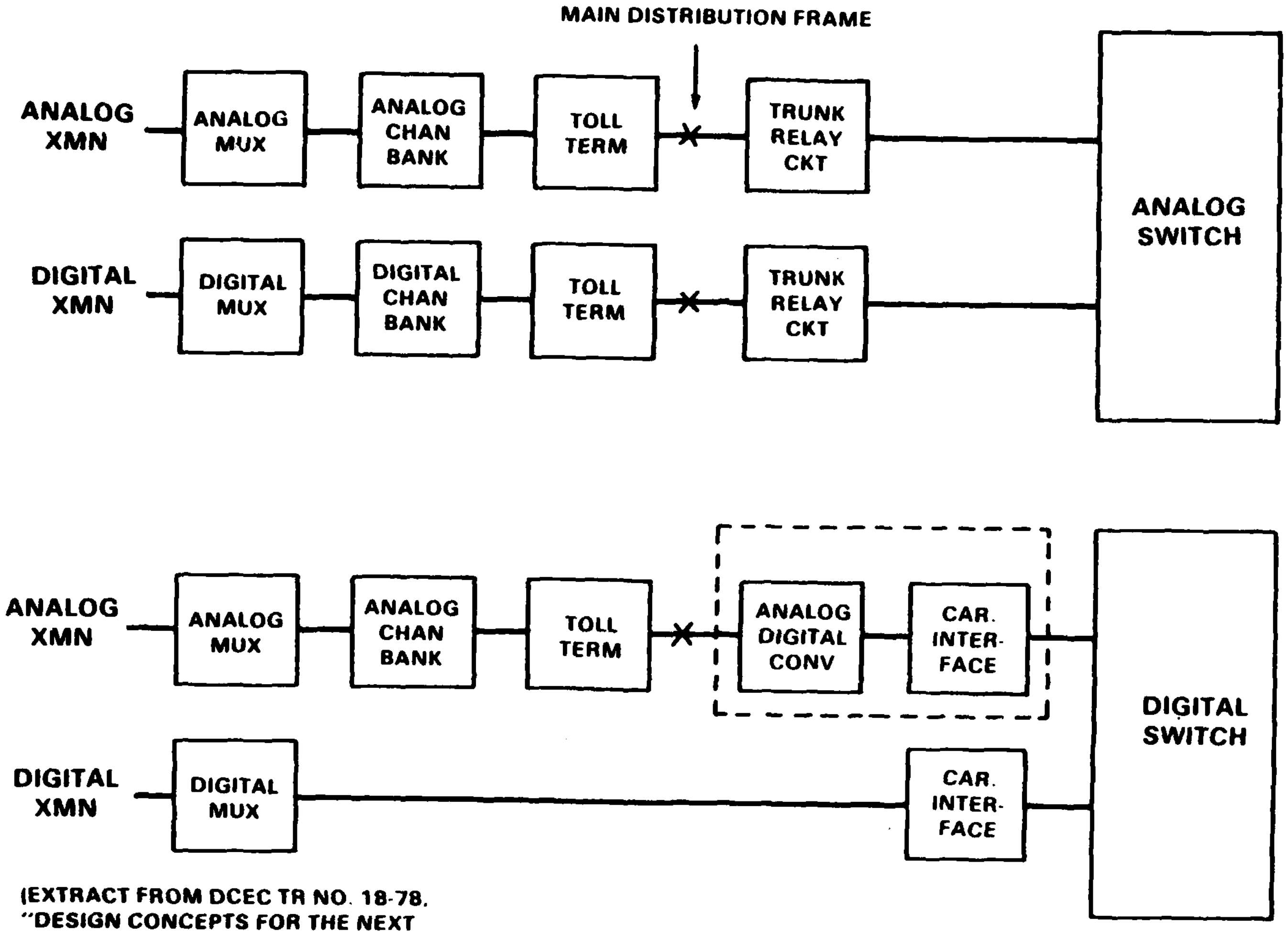
The CONUS DSN (CDSN) will be implemented in (and because of) a changing regulatory and political environment. A telecommunications system in the CONUS cannot be implemented by the government (DOD/DA) unilaterally (in the sense of military-unique, weapon system acquisitions). Therefore, the environment external to the DA and to the DOD is the context for describing the functions of the CDSN.

## A.2 TECHNICAL CHARACTERISTICS

In the CDSN and its associated postulated Next Generation CONUS AUTOVON, digital switches would not only perform the functions normally associated with conventional central offices, PBX and Centrex switches, and tandem switches, but they would also perform the functions associated with technical controls and terminating facilities.

The top string of blocks in Figure 3 shows the relationship of the multiplex equipments, channel banks, toll terminating facilities, trunk relay circuits, and analog switches as configured in the current CONUS DCS network. All elements to the left of the "x", representing the main distribution frame (MDF), are located in what are called "technical controls" in DCA terminology. In the commercial world, these elements are maintained by the trunk maintenance force, while all elements to the right of the MDF are maintained by the equipment (or switch) maintenance force.

Note that when digital switching and digital transmission are combined, as depicted by the bottom line of the figure, most of these




(EXTRACT FROM DCEC TR NO. 18-78,
"DESIGN CONCEPTS FOR THE NEXT
GENERATION CONUS AUTOVON"
DEC. 1978
4961/BGW

Figure 3. The advantages of an integrated network.

elements are eliminated. However, during an interim hybrid period, the configurations represented by the two middle lines of the figure will be the case in the real world. The figure also shows, then, that a transition to the bottom line configuration is achievable on an evolutionary basis and such a strategy is being pursued in the commercial world.

With a CDSN utilizing the new digital switches, dedicated time slots can be "nailed up" under firmware or software control of the digital switches. "Dedicated time slot" connections will undoubtedly create some uneasiness among dedicated users because they appear to be a switched connection. In fact, they could be just as reliable or more reliable than dedicated circuits using the technology of the 1960's. All digital switches on the market today are capable of "dedicated time slot" service, thus performing the functions of an automated patching and wiring facility.

The AT&T and the U.S. Independent Telephone Association (USITA) have already developed a wide range of hardware, software, and firmware standards and procedures and automated test equipment in connection with the Bell System Digital Data Service (DDS) offering. Although much of this applies to data services over analog facilities, considerable work has already been accomplished and tested in the market place for application over T1-oriented facilities. There is no reason why much of this cannot be applied to the CDSN for providing "dedicated time slot" data services.

In the Bell System's digital No. 4 ESS, wherever direct T1 interfaces are implemented, the patch bays and much of the toll terminating facilities have been eliminated, as depicted in the bottom line of Figure 3. This is also true with digital end offices with T1 lines interconnecting to remote switching units. These techniques are rapidly being employed in the No. 4 ESS facilities, digital end offices, and digital PBX's. It would therefore seem reasonable to assume that the CDSN will integrate the functions of channel banks in multiplexers, terminating equipments, and many of the audio frequency patch bays that are familiar to the military communicator in Government-owned technical controls. They can be operated with far less personnel per circuit terminated or per erlang switched.

The transmission media for the current AUTOVON consist of inter-switch trunks (voice channels) and access lines (voice channels) which are dedicated to AUTOVON and not accessible for message telephone service (MTS or telephone service for the general public). This also implies that the total vast resources of the Bell System and the Independents are not available to AUTOVON users, particularly, the 4-wire subscribers who enjoy the benefits of Multi-level Precedence Preemption (MLPP).

The postulated Next Generation CONUS AUTOVON takes advantage of virtually the entire telecommunications resources in the Continental United States as depicted in Figure 4.

The figure also highlights the advantages of each element of the Mix of Media. Current plans of satellite carriers who plan to offer small satellite terminal services in the 12-14 GHz spectrum promise economical services even over less than transcontinental distances, and economical services which require multi-megabit transmission. The Bell System is forecasting a great number of additional features via its network of No. 4 ESS and Common Channel Switching (CCS). It has recently committed itself to the development of the No. 5 ESS for digital switching services in the exchange areas. With more than 15,000 of these end offices in the United States, it would be prudent to assume that conversion to digital operation here would require an extended period of time past the 1982-1992 period of interest. Regional switches are postulated where economical in the Next Generation CONUS AUTOVON. The locations could be identical to those being sponsored under the Defense Metropolitan Area Telephone Systems (DMATS).

By utilizing commercial off-the-shelf hardware and modified off-the-shelf firmware/software, it is technically feasible to provide a host of features at CDSN switch or concentrator locations close to the subscriber (see Figure 5). The basic technology which has made this possible is the large-scale integrated circuit without which digital switching would be impractical. The number of components is increasing 100% per year with the number of functions already surpassing the one million mark.

- **SATELLITES**
  - VERY LONG DISTANCE TRANSMISSION AT LOW COST
  - MULTI-MEGABIT TRANSMISSION
- **NO. 5 ESS, NO. 4 ESS/TD-2 MICROWAVE, L-5 CARRIER**
  - LONG AND MEDIUM TRANSMISSION AT LOW COST
  - FLEXIBLE COMMUNICATIONS IN CRISIS & WAR
- **T1 LINES/METALLIC OR FIBER OPTIC**
  - SHORT DISTANCE TRANSMISSION AT LOW COST
  - LOW COST DATA TRANSMISSION UP TO 56 KBS
- **REGIONAL AUTOVON SWITCHES/T1 LINES**
  - ECONOMICAL IN CERTAIN REGIONS WITH CLUSTERS OF DOD USERS

4951/80W

Figure 4. CONUS DSN mix of media derived via the Next Generation CONUS AUTOVON.

(1) Multi-Level Precedence Preemption (MLPP) - Preemption is the right of seizing and using the equipment on preference over subscribers assigned a lower precedence. Those having this privilege can obtain access to available circuits in preference to other subscribers and where all circuits are in use, the higher precedence may force a caller of lower precedence to relinquish circuits required to complete the call.

(2) Conferencing - Arrangements are in two main categories: automatic (or preset) and random (or selective) conferences.

  (a) Automatic conferencing permits an authorized subscriber to be connected simultaneously to a predetermined, fixed group of subscribers. Each preset conference is assigned a level of precedence as authorized.

  (b) Random conferencing permits a subscriber simultaneous connection to two or more subscribers. The originator of the conference can choose conferences at random.

(3) Off-Hook Service - A subscriber, upon lifting the handset of his telephone, is immediately connected to a predesignated subscriber.

(4) Precedence Alerting - A distinctive audible and/or visual signal to indicate whether an incoming call is of PRIORITY or higher precedence.

(5) Automatic Traffic Overload Protection - This control functions at a predetermined traffic load level to reduce or exclude all originations from subscribers identified by the customer as being subject to this control.

(6) Voice Message Storage - A call can be stored by the switch for delivery at a later time if the called party is absent.

(7) Remote Call Forwarding - Calls to a called party could be remoted to a location where he may be temporarily located, e.g., for TDY.

(8) Alternate Voice/Data - Up to 56 kilobits per second for users who require high speed facsimile, access to computers, and the like.

(9) Digital Connection Services - AUTOSEVOCOM, AUTODIN, or special purpose users.

Figure 5. Features that could be located close to the CDSN user.

These developments have made it possible to find switches on the commercial market that could easily perform the features listed in Figure 5 or equivalent features at the PBX or base central office level. As a matter of fact, the rapid advance of this technology indicates that the "smarts" or "intelligence" could be located at the user station itself some time within the 1982-1992 time frame.

At least one vendor has already made a commitment for the MLPP software package, and its cost will be a function of the number of such switches fielded for amortizing the software development. It is also possible (if there is a DOD policy change on this requirement) that a two-level precedence feature could be provided with off-the-shelf firmware/software, thus amortizing the software development over a large number of switches.

Conferencing features are provided with off-the-shelf digital switches on the market. Priority diversion equivalent service can be provided with off-the-shelf hardware/firmware/software although the exact means of providing this feature may not conform exactly to what is provided today.

Equivalent precedence alerting service may be provided with equipment currently available on the market. The nature of automatic traffic overload protection will be different in the future. Nevertheless, this feature can be provided with off-the-shelf hardware and software.

The configuration represented by Figure 6 appears within the realm of feasibility. For simplicity and clarity, only the digital elements of the configuration are depicted. PCM channel banks would be required for interfaces with all analog users.

All AUTOVON, AUTODIN, Secure Voice, and Special Purpose traffic would be carried via time slots either "nailed up" or with traveling class marks via CCIS. The DCA could then be charged for the fraction of time slots utilized compared to the total time slots available. Hardware investment costs are shared with the general public. Software investment costs would depend on the features required by the user.

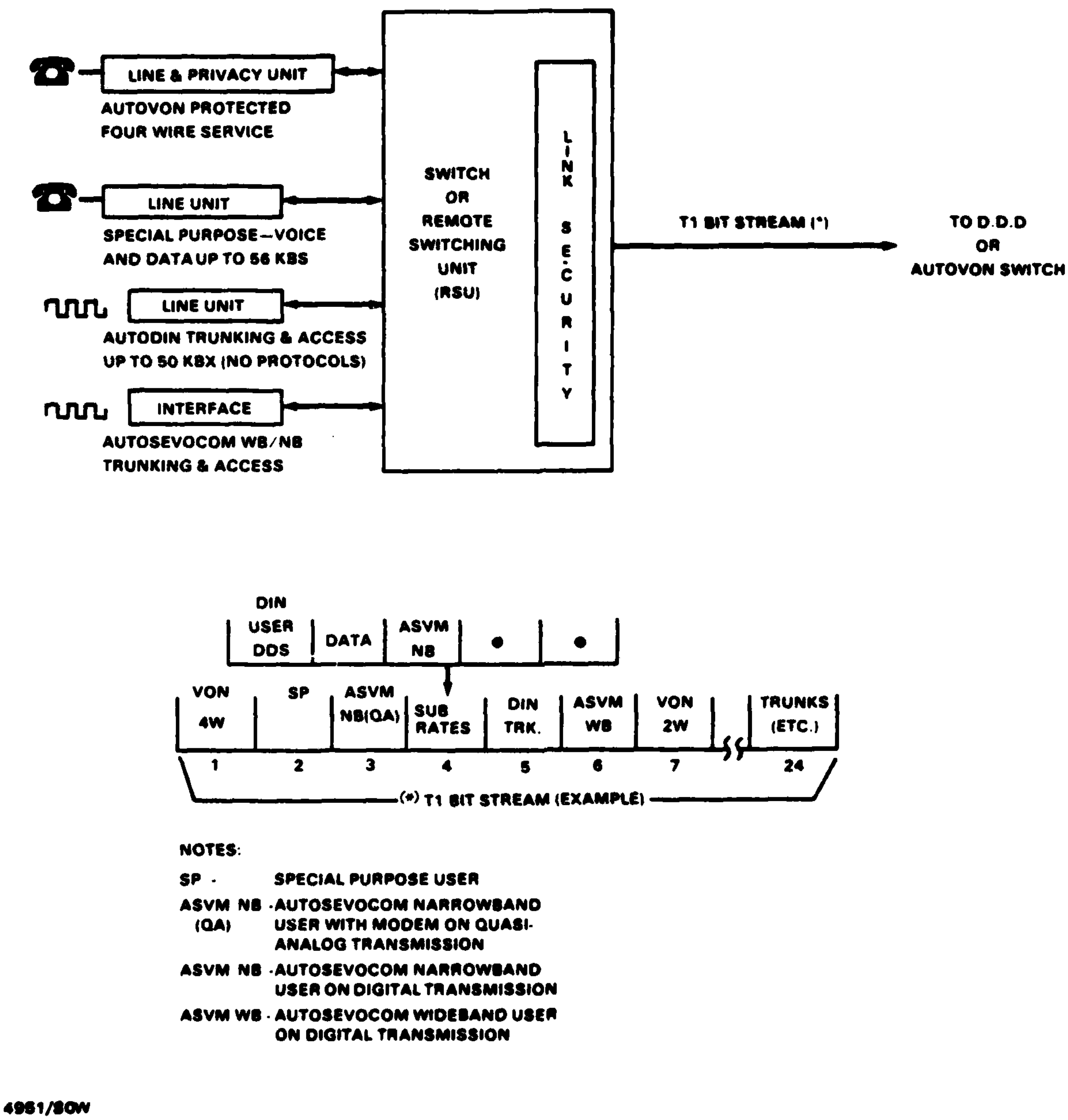



Figure 6. CDSN integration of network services.

This configuration could be realizable in the mid to late 1980's, provided military departments, DCA, and the commercial carriers are all in step. The potential is very high for achieving an integrated voice and data network with this appraoch. To date, there are no assurances that this feature will be offered in CONUS as a commercial tariff.

The anticipated mode of commercial satellite services is TDMA, operating in the 12-14 GHz band, with a ground terminal providing a G/T in the 30-33 db/°K range. (Present terminals do not operate in this frequency range.) This (1981-83) capability will make possible small, economical satellite terminals which can be sited on the user's premises (base-post, camp, or station).

The rapid proliferation of the (commercial) No. 4 Electronic Switching System indicates extensive digital switching will be available by 1992. By 1982, there will be nearly 90 operational No. 4 ESSs.

A.3 OPERATIONAL CHARACTERISTICS

The DSN shall provide survivability for secure and non-secure FLASH and IMMEDIATE precedence users from the command and control, operations, intelligence, and logistics communities. High precedence service will be fully integrated in the CDSN or provided by means of a sub-network within the CDSN.

The CDSN shall automatically provide "Least Cost Routing" for lower precedence calls. Appropriate "automatic" message accounting will be employed to message and control calling.

Leasing of commercially available facilities and/or services is preferred to government-owned facilities (cost savings and military necessity are reasons for exception). The DMATS and the military base (post, camp, or station) electronic switches obtained before CONUS DSN planning is complete must include switch features which permit (at least in part) operation as part of the AUTOVON, and as $C^2$ access or tandem switches.

By the use of automatic monitoring techniques, commercial carriers have demonstrated remote performance monitoring functions that represent significant improvements over analog techniques.

Instead of dual-routed dedicated circuits or dual homing on backbone-type switches (e.g., AUTOVON), CDSN survivability (connectivity) will be achieved through a mix of media and of commercial facilities as shown previously by Figure 4.

The CDSN concept calls for improved responsiveness in meeting the operational needs of the National Command Authorities (NCA). The network control becomes a critical mechanism function in a CDSN because commercial capabilities will need to be manipulated quickly and repeatedly because of the dynamics associated with NCA-managed situations. The CDSN will function in a distributed mode in peacetime and change to centralized control in crisis and in war. The essence of the DCS operational direction of the CDSN is summarized in Table 1.

Table 1. Operational direction of the CONUS DSN.

| Situation | Description of Control | Availability |
|---|---|---|
| • Peacetime | | |
| Least Cost Routing | Control by Resident Firmware and Software at Local Central Office on Post, Camp, Station | Available With Off-the-Shelf PBX's and End Offices. |
| Special Purpose Users and AUTOVON 4-Wire Users | Dedicated Time Slots Under Control of Resident Firmware and Software at Local Central Office on Post, Camp, Station | Available With Off-the-Shelf PBX's and End Offices.<br><br>Available With No. 4 ESS/ |
| • Wartime or Crisis Conditions | | |
| Control by DCA in Accordance With Modified DCA Operational Direction Role & Mission | Centralized Control Exercised by DCA's DOCC Complex Upon Direction From JCS-J3 and the National Command Authority. Dynamic Dedicated Time Slots Exercised Via the Bell System's No. 4 ESS Network | Software and Firmware not Available. Possibility of Modified Software for Related Applications by AT&T for Communications During Natural Disasters. |

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## APPENDIX B
## NON-DOD KEY USERS

### B.1 INTRODUCTION

The Federal Emergency Management Agency, the agency that coordinates national emergency preparedness activities, maintains a list of 38 Category A Federal departments, agencies, and offices which would require essential, non-interruptable communications capability during the trans-attack and early post-attack periods of a general nuclear war to carry out their critical missions. This list is presented below with additional civil agencies which have significant functions relating to attacks on the United States. These additional agencies include executive heads of the 50 states, the District of Columbia, Puerto Rico, Guam, and the Virgin Islands. Also included are Federal activities such as elements of the Federal Aviation Administration (crucial air traffic control for military and civil flights), the eight Federal Regional (Emergency) Centers, and subsidiaries of the Federal Communications Commission (critical communications control). The locations presented to the right of these users are peace-time headquarters.

### B.2 EXECUTIVE DEPARTMENTS

| | |
|---|---|
| Department of State | Washington, DC |
| Department of Defense | Washington, DC |
| Department of the Treasury | Washington, DC |
| Department of Justice | Washington, DC |
| Department of the Interior | Washington, DC |
| Department of Agriculture | Washington, DC |
| Department of Commerce | Washington, DC |
| Department of Labor | Washington, DC |
| Department of Health, Education* & Welfare | Washington, DC |
| Department of Housing and Urban Development | Washington, DC |

* Roles of the new Department of Education are not yet clear.

| | |
|---|---|
| Department of Energy | Washington, DC |
| Department of Transportation | Washington, DC |
| Federal Aviation Administration | Washington, DC |
| Eastern Region | Jamaica, NY |
| Central Region | Kansas City, MO |
| Great Lakes Region | Des Planes, IL |
| New England Region | Burlington, MA |
| Northwest Region | Seattle, WA |
| Rocky Mountain Region | Aurora, CO |
| Southern Region | Atlanta, GA |
| Southwest Region | Fort Worth, TX |
| Western Region | Los Angeles, CA |
| Alaskan Region | Anchorage, AK |
| Pacific-Asian Region | Honolulu, HI |
| Europe-Africa-Middle East Region | Brussels, Belgium |
| Federal Regional (Emergency) Centers | |
| Regional Center 1 | Maynard, MA |
| Regional Center 2 | Olney, MD |
| Regional Center 3 | Thomasville, GA |
| Regional Center 4 | Battle Creek, MI |
| Regional Center 5 | Denton, TX |
| Regional Center 6 | Denver, CO |
| Regional Center 7 | Santa Rosa, CA |
| Regional Center 8 | Bothell, WA |

B.3 EIGHTEEN INDEPENDENT AGENCIES

| | |
|---|---|
| Federal Emergency Management Agency | Washington, DC |
| Civil Aeronautics Board | Washington, DC |
| Environmental Protection Agency | Washington, DC |
| Federal Communications Commission | Washington, DC |
| Regional Office | Boston, MA |
| Regional Office | Kansas City, MO |
| Regional Office | San Francisco, CA |

| | |
|---|---|
| Common Carrier Bureau | New York, NY |
| Common Carrier Bureau | St. Louis, MO |
| Federal Reserve Board | Washington, DC |
| General Services Administration | Washington, DC |
| Government Printing Office | Washington, DC |
| International Communications Agency | Washington, DC |
| Interstate Commerce Commission | Washington, DC |
| National Aeronautics and Space Administration | Washington, DC |
| National Communications System | Arlington, VA |
| National Telecommunications Information Agency | Washington, DC |
| Nuclear Regulatory Commission | Washington, DC |
| Office of Personnel Management | Washington, DC |
| Selective Service System | Washington, DC |
| Tennessee Valley Authority | Knoxville, TN |
| United States Postal Service | Washington, DC |
| Veterans Administration | Washington, DC |

B.4 EIGHT EXECUTIVE OFFICES

| | |
|---|---|
| White House Offices | Washington, DC |
| Central Intelligence Agency | Washington, DC |
| Council of Economic Advisors | Washington, DC |
| Domestic Affairs and Policy Staff | Washington, DC |
| National Security Council | Washington, DC |
| Office of Management and Budget | Washington, DC |
| Office of Science and Technology Policy | Washington, DC |
| Office of Administration | Washington, DC |

B.5 STATE AND LOCAL GOVERNMENTS

| | |
|---|---|
| State Governors | All 50 States |
| Mayor | District of Columbia |
| Governor | Puerto Rico |
| Governor | Guam |
| Governor | Virgin Islands |

Blank

# APPENDIX C
# CRITICAL MILITARY USERS

## C.1 INTRODUCTION

Priorities for military communications vary widely, depending upon the situation at the time of need. However, among critical DOD users of dedicated DCS communications, one possible priorization based on functional need is as follows:

(1) Immediation attack assessment users,
(2) Emergency action messages receipients,
(3) Aerospace defense centers,
(4) Commands and agencies marshalling active duty forces,
(5) National Guard and Reserves mobilization centers, and
(6) Civil assistance users.

This categorization is based on functional urgency and is therefore preferred to the AUTOVON and AUTODIN precedence (FLASH, IMMEDIATE, PRIORITY, and ROUTINE).

One point needing clarification concerns the users located outside the United States and therefore not directly served by the domestic PTN. Telephone communications for agencies outside the United States would need routing through domestic gateway switches. These potential overseas users are listed along with potential domestic users.

The following subsections present possible listing of the various DOD users in each of the functional categories listed above. In general, the listings address only major commands and agencies but not their subordinates. The following lists are for the purpose of illustrating the scope and magnitude of such an identification effort, and are not intended to be comprehensive nor final.

## C.2 IMMEDIATE ATTACK ASSESSMENT USERS

| | |
|---|---|
| President<br>Secretary of Defense (SECDEF) | National Command Authorities |

National Command Authorities Alternatives
Joint Chiefs of Staff (JCS)
National Military Command Center (NMCC)
Alternate National Military Command Center (ANMCC)
National Emergency Airborne Command Post (NEACP)
NORAD Command Center
SAC Command Center
LANTCOM Command Center
PACOM Command Center
US EUCOM Command Center
Allied Heads of Government

C.3 EMERGENCY ACTION MESSAGES RECIPIENTS

Eighth Air Force
Fifteenth Air Force
Third Air Division
Fleet Submarine Broadcast Stations
- Cutler, ME
- Annapolis, MD
- Jim Creek, WA
- Overseas Stations

TACAMO PAC
TACAMO LANT
ICBM Launch Control Centers
- Davis-Monthan AFB, AZ
- Malmstrom AFB, MT
- F.E. Warren AFB, WY
- Minot AFB, ND
- Grand Forks AFB, ND
- McConnell AFB, KS
- Whiteman AFB, MO
- Little Rock AFB, AR

Bomber Bases
- Fairchild AFB, CA

Beale AFB, CA
Mather AFB, CA
Castle AFB, CA
March AFB, CA
Glasgow AFB, MT
Grand Forks AFB, ND
Ellsworth AFB, ND
Davis-Monthan AFB, AZ
Dyess AFB, TX
Carswell AFB, TX
Blythville AFB, AR
Barksdale AFB, LA
K.I. Sawyer AFB, MI
Wurtsmith AFB, MI
Robins AFB, GA
Plattsburgh AFB, NY
Griffiss AFB, NY
Seymour Johnson AFB, NC
Pease AFB, NH
Loring AFB, ME
Andersen AFB, Guam
Kadena AFB, Okinawa

Tanker Bases

Altus AFB, OK
Grissom AFB, IN
Rickenbacker AFB, OH
Travis AFB, CA

Submarine Bases

Bremerton, WA
Charleston, SC
Kings Bay, GA (under construction)

Nuclear Forces Overseas

- Second Fleet
- Third Fleet
- Sixth Fleet
- Seventh Fleet
- USAREUR
- V Corps
- VI Corps
- USAFE
- Third Air Force
- Sixteenth Air Force
- Seventeenth Air Force
- U.S. Forces Korea
- U.S. Forces Japan
- U.S. Taiwan Defense Command

C.4 AEROSPACE DEFENSE CENTERS

NORAD 20th Region Control Center
NORAD 21th Region Control Center
NORAD 22nd Region Control Center
NORAD 24th Region Control Center
NORAD 25th Region Control Center
NORAD 26th Region Control Center
Alaskan Region Control Center

Within the 48 contiguous United States the six existing Region Control Centers will be replaced by four Region Operations Control Centers by 1983.

C.5 COMMANDS AND AGENCIES MARSHALLING ACTIVE DUTY FORCES

Alaskan Air Command (Joint Task Force-Alaska)
Military Airlift Command (MAC)
U.S. Readiness Command (USREDCOM)
U.S. Southern Command
Army Operations Center

Navy Operations Center
Marine Corps Operations Center
Air Force Operations Center
FORSCOM Command Center
TRADOC Command Center
DARCOM Command Center
Army Communications Command
CINCLANTFLT
FMFLANT Command Center
CINCPACFLT
FMFPAC Command Center
Naval Telecommunications Center (NTC)
Naval Material Command (NAVMATCOM)
Tactical Air Command (TAC)
Air Force Logistics Command (AFLC)
Pacific Air Forces (PACAF)
Air Force Communications Command (AFCC)
Defense Communications Agency (DCA)
Defense Logistics Agency (DLA)
Defense Mapping Agency (DMA)
Defense Nuclear Agency (DNA)
National Security Agency (NSA)

C.6 NATIONAL GUARD AND RESERVES MOBILIZATION CENTERS

Adjutant Generals of the Fifty States, Puerto Rico, Virgin Islands, and District of Columbia
National Guard Bureau
Nine Army Reserves Region Headquarters
Air Force Reserves Headquarters
Air Force Reserves Region Headquarters

C.7 CIVIL ASSISTANCE USERS

First Army
Fifth Army

Sixth Army

Six Marine Corps Districts

Military Traffic Management Command

Military Sealift Command

# APPENDIX D
# CURRENT SYSTEM DESCRIPTION

## D.1 INTRODUCTION

The general current description of the public telephone network (PTN) is presented in this appendix. As concentration and interest in this effort is on the feasibility of a wartime switching router, the current system description presented will reflect this interest. The information gathered and presented here concerns the switching principles and electronic switching systems used in the PTN.

Subsection D.2 discusses the switching principles of the PTN and Subsection D.3 presents the concepts of the electronic switching systems (ESSs). In Appendix F is provided information on the No. 1 through No. 4 Electronic Switching Systems.

## D.2 SWITCHING PRINCIPLES

### D.2.1 Function and Structure

In circuit switching a communications path is established when a called party goes off hook in response to a ring signal initiated when a calling party enters the proper directory listed number into the switching system. Thus a dedicated path capable of simultaneous two-way conversational communications is established between the two parties.

A circuit switch consists of a set of circuits (lines) used to interconnect a set of ports (destinations). This type of switch can be simply modeled as a set of n input ports and n output ports; a set of circuits connect every input port to every output port.

Two concepts used in the PTN, full access and nonblocking, form a basis from which the telephone system is capable of being a dependable public service. Full access means that every subscriber can be connected to every other subscriber, although not necessarily at the same time. Nonblocking is defined to be the capability that any subscriber can be connected to any idle subscriber, regardless of the number of existing connections.

The telephone network, while being fully accessible, is not truly nonblocking. For any given switching station, normally only 10 to 14 percent of its subscribers require service at any one time. Thus, the switching network is only required to simultaneously handle that percentage of its subscribers.

The PTN structure for the U.S. and Canada is characterized by a five level hierarchy of switching offices, as depicted in Figure 7. This area is divided into 12 regions, each region containing one switching office of the highest level. A trunk group called a final group connects a switching office to the next higher level switching office (except at the highest level) within a region. The final groups ensure the existence of a path from any switching office in the network to any other. Other trunk groups are used to connect switching offices (not necessarily of the same level) where there exists a sufficient amount of traffic. These trunk groups are called high-usage groups.

Several types of trunk circuits are also connected to the class 5 office or end office. Interoffice trunks, which could be high-usage trunks, interconnect end offices. A final trunk group connects the end office to its assigned toll center (class 4 office) as part of the hierarchical structure and for direct distance dialing (DDD) facilities. Finally, tandem trunks interconnect tandem and end offices; a tandem office is an intermediate switching system which interconnects end and toll offices.

### D.2.2 Switching Control

The two types of switching networks used in the PTN are the space division network and the time-division network. The former establishes its own physical path through the network, perhaps one stage at a time. In contrast, the time-division network is capable of handling more than one conversation on the same physical path, by the use of gates for a number of telephones connected together to a common bus. When two parties wish to converse, their associated gates must operate simultaneously. Although the two telephones are not physically connected, voice signals can still pass between them because of the speed and simultaneous action of the gates.

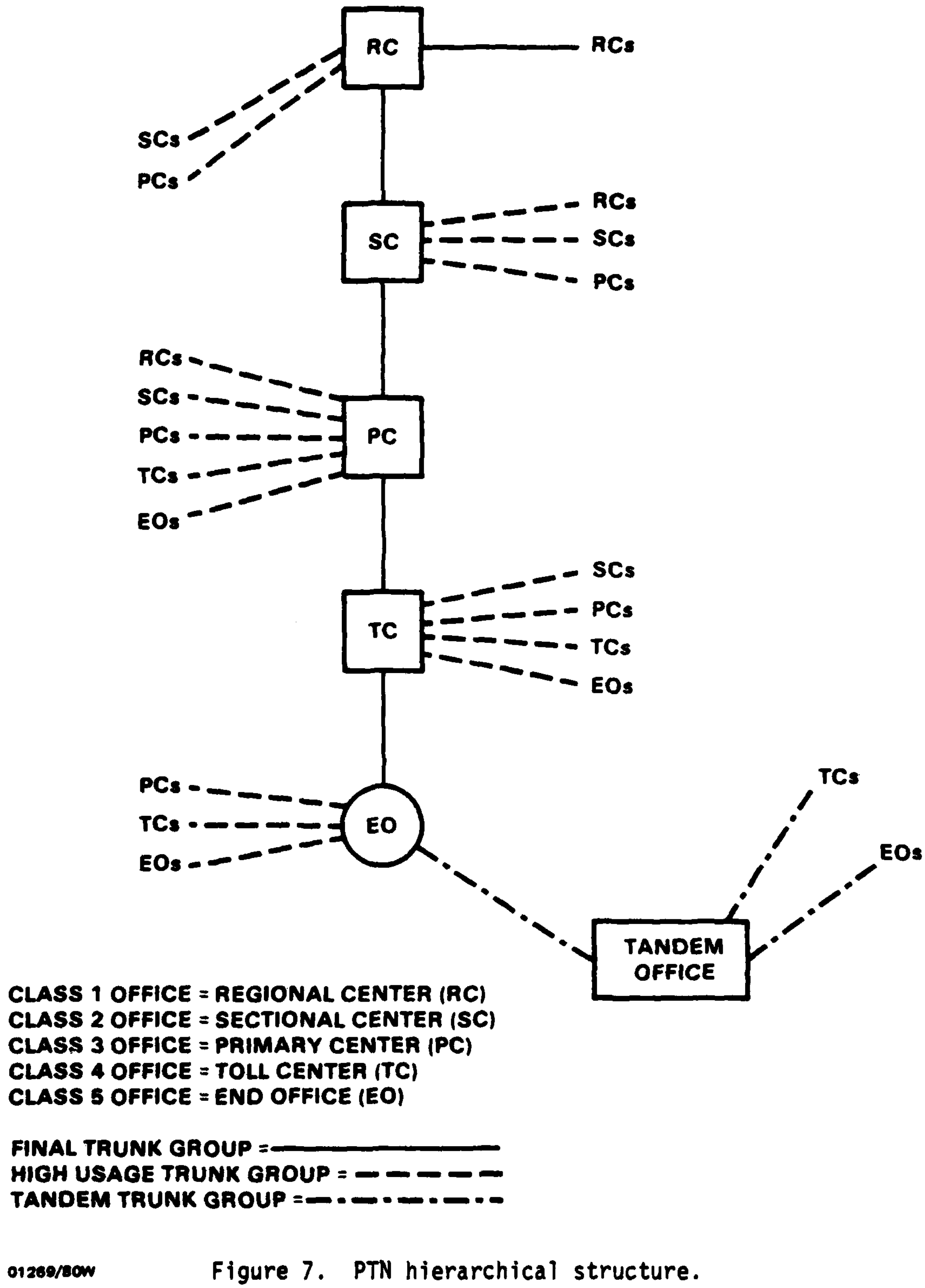


Figure 7. PTN hierarchical structure.

All switching networks require a controlling mechanism; control involves finding the idle terminals that wish to use the network, hunting for and selecting paths, and establishing connections. The most elementary type of control is termed direct progressive control. As switching systems evolved, indirectly controlled and common controlled switching were developed. These types of switching have alternate routing capabilities when blocking occurs. Finally, with the advent of electronic switching, stored program control was designed.

A directly controlled progressive system is controlled by dial pulses (from one to ten depending on the number dialed) transmitted by the subscriber. The control switch, which has 10 outlets, is stepped in response to the impulses from the dial, making one step for each pulse. Thus, a path is progressively established through the network until the called customer's line is reached.

The system has several major drawbacks, to include:

(1) The called number specifically locates the called line on the last switching stage,

(2) Alternate routing is not possible, and

(3) The network needs considerable spare capacity because it cannot look ahead to see if the path being established will be blocked.

These problems have been alleviated by the indirect progressively controlled system which introduces a register to collect the dialed digits. The dialed digits are translated into switching control digits which are pulsed to the rest of the network to make the proper connection. Thus, if blocking occurs, the dialed number is still available and rerouting is possible.

The common control system, like the indirect progressively controlled system, uses separate control registers. In particular, there is an additional control unit called a marker. The marker translates the office code information and locates an idle trunk to the terminating office; this office, in turn, locates an idle terminating register. When

all connections have been established the marker informs the originating register that it should transmit the called number. The terminating register, however, must connect to it so that the final connections can be made. The marker must determine the switch location of the called number, test the line for an idle or busy condition, and make the proper connections before its job is complete.

In a stored program system, the function of a marker can be performed by an electronic processor. With this processor, translation changes and other modifications can be implemented as changes in the program rather than as hardware changes. The central processor can simultaneously handle (time-sharing of control) many calls in various stages of completion. It executes one function per call in a very short time interval and then progresses to some other function, either on the same or a different call.

## D.3 CONCEPTS OF ELECTRONIC SWITCHING SYSTEMS

The development of electronic switching systems has been the result of many new concepts which are entirely different from the designs of previously used electromechanical systems. See Appendix F. Stored program methods including programmed logic and temporary memory techniques are employed. The program instructions for handling a call employ binary symbols and other machine language elements (software). The subsequent translation and interpretation of these instructions are directed by wired logic in a central control unit. Basic elements of an electronic switching system include the central processor, scanner circuits, signal distributors, central pulse distributor and trunk junctor, and service circuits.

The central processor is the most important element of common control in electronic switching systems. The central processor, a high-speed computer and data processing unit, is the "brains" of the system. Its three basic components, as shown in Figure 8, are central control, program store, and call store.

Central control is a computer-type binary digital mechanism that performs logic operations in accordance with instructions in its

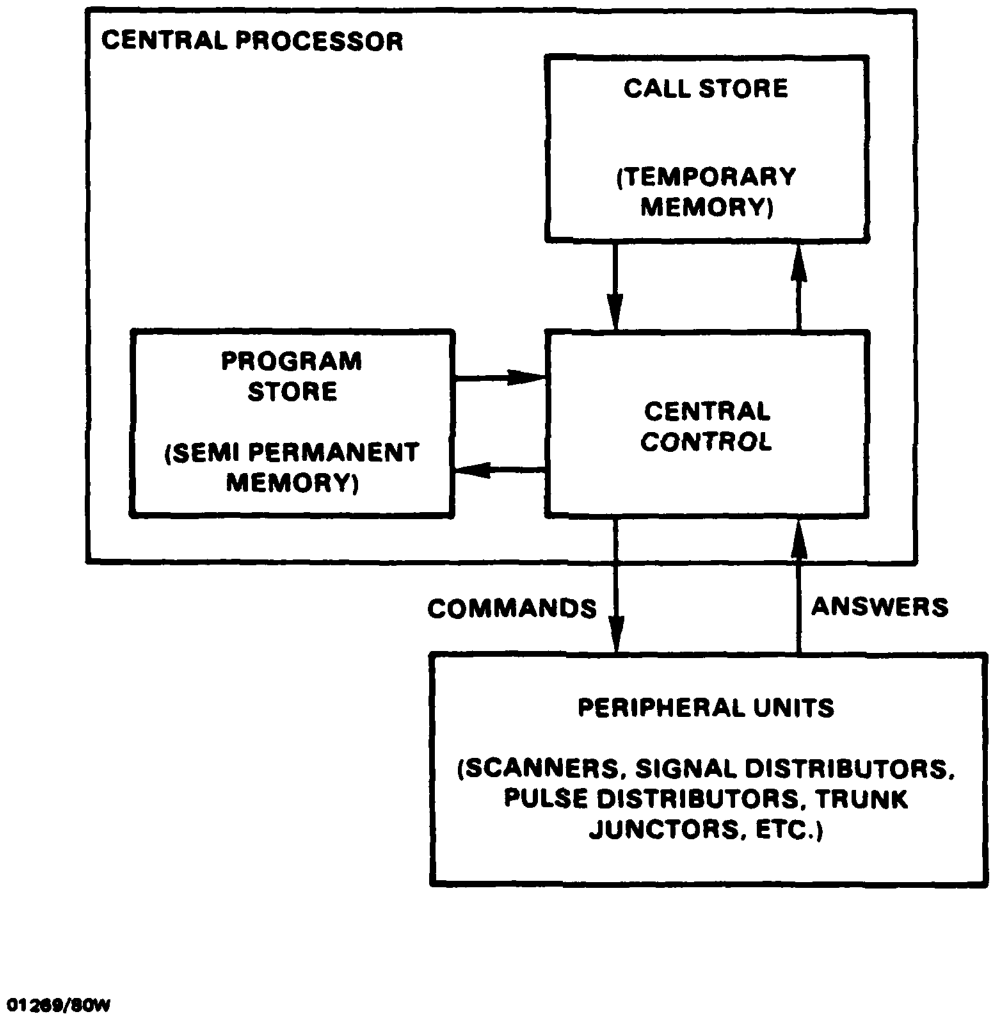


Figure 8. Central processor and interfaces.

semi-permanent program store and temporary call store memories. Normally, three major classes of instructions are processed by central control:

(1) The status of lines and trunks such as on-hook and off-hook,

(2) Manipulating data received from program store and temporarily depositing the results in call store for recall, and

(3) Generating outputs for operating latching relays in junctor, trunk, and service circuits.

To process the instructions, central control requests applicable information from its program and call stores.

The program store is a semipermanent memory device that contains specific instructions governing the step-by-step operations of central control. The data contained in program store includes information for locating a customer's line, locating trunk locations, routing and charging information, and other items concerning particular lines or trunks.

The call store is a temporary memory unit that is used to record information pertaining to a call in progress. Data temporarily deposited in call store may include the dialed digits, idle or busy status of links in the switching network, charge information, and digits to be transmitted on an outgoing call. In addition, changes in translation information, such as routing a call to a particular office, can be temporarily stored in call store until these instructions can be placed in program store.

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# APPENDIX E
# HISTORY OF SWITCHING SYSTEMS

## E.1 INTRODUCTION

This appendix provides some background on the development of switching in the PTN, intended as information to follow the discussion in Appendix D on directly controlled, indirectly controlled, and common control systems. In the next subsection is presented some of the developments in switching systems from the earliest days to the No. 1 Crossbar. Subsection E.3 outlines a few of the toll offices installed since the first installation in 1920. Finally, in Subsection E.4 is discussed the No. 5 Crossbar, which is the most sophisticated electromechanical switching system developed by the Bell System. Electronic switching systems are discussed in Appendix F.

## E.2 EARLY DAYS

In the early days of telephony, people bought telephones in pairs; two parties were connected to each other by dedicated line. Soon common lines (usually between professional interest groups) were utilized. A ringing code identified which station on the line was being contacted. Then came the need for the telephone switchboards as the various interest groups and residential subscribers wanted to talk to one another.

When the first switchboard was used, a person desiring to make a call would "ring" the operator, who identified which line wanted service by inserting a plug and cord into the proper jack. The operator could then verbally ascertain whom the caller wanted and make the proper connection by inserting another plug (connected to the caller's plug) into the called party's jack. A ringing code was applied to the called person's line; the operator disassociated from the connection when the ringing was answered. A ring-off signal indicated to the operator that the conversation was over and that the connection could be "taken down."

The need for automatic switching initially arose in small communities where it was unnecessary and uneconomical to employ 24-hour operators. The need for automation was further accelerated by the rapid growth

of metropolitan areas, where operators were unable to handle the increased volume of calls. Electromechanical switching systems provided the needed automation and provided the means of interconnecting on demand any two subscribers in the PTN.

The first electromechanical switching system developed by the Bell System was called the Step-by-Step. This system is a direct, progressive control system in which the selecting switches are directly controlled by the pulses generated by a dialed number.

For example, consider the 10,000 line Step-by-Step system shown in Figure 9 (customers would be numbered from 0000-9999). When the customer goes off-hook, an idle line finder locates the line through a vertical and horizontal hunt. A dial tone is returned to the caller by a selector switch wired to the line finder. Next, this selector switch moves upward in accordance to the first digit dialed and moves horizontally across this row to find a circuit to the next idle selector switch. The second selector switch is controlled by the second dialed digit. This switch connects, through the same process, to an idle connector switch which is controlled by the third and fourth digits. The third digit steps the switch vertically and the fourth moves the switch horizontally to the dialed line. Finally, either a ring or busy signal is applied depending on the state of the line.

The Panel Dial System, a common, progressive control system, followed shortly after installation of the Step-by-Step. This system was developed to replace manual central offices in the larger cities. As Figure 10 depicts, this system had five major categories of vertical selector switching frames: line finder, district, office frames, incoming, and final frames. The sender and decoder circuits are used as the principal common-control devices.

A line finder is used to locate the requesting line. The sender, in turn, provides dial tone, temporarily stores the dialed digits, and connects to a decoder circuit, which translates the first three digits (office code) into proper routing instructions which are sent back to the sender. The sender now dismisses the decoder and controls the selection

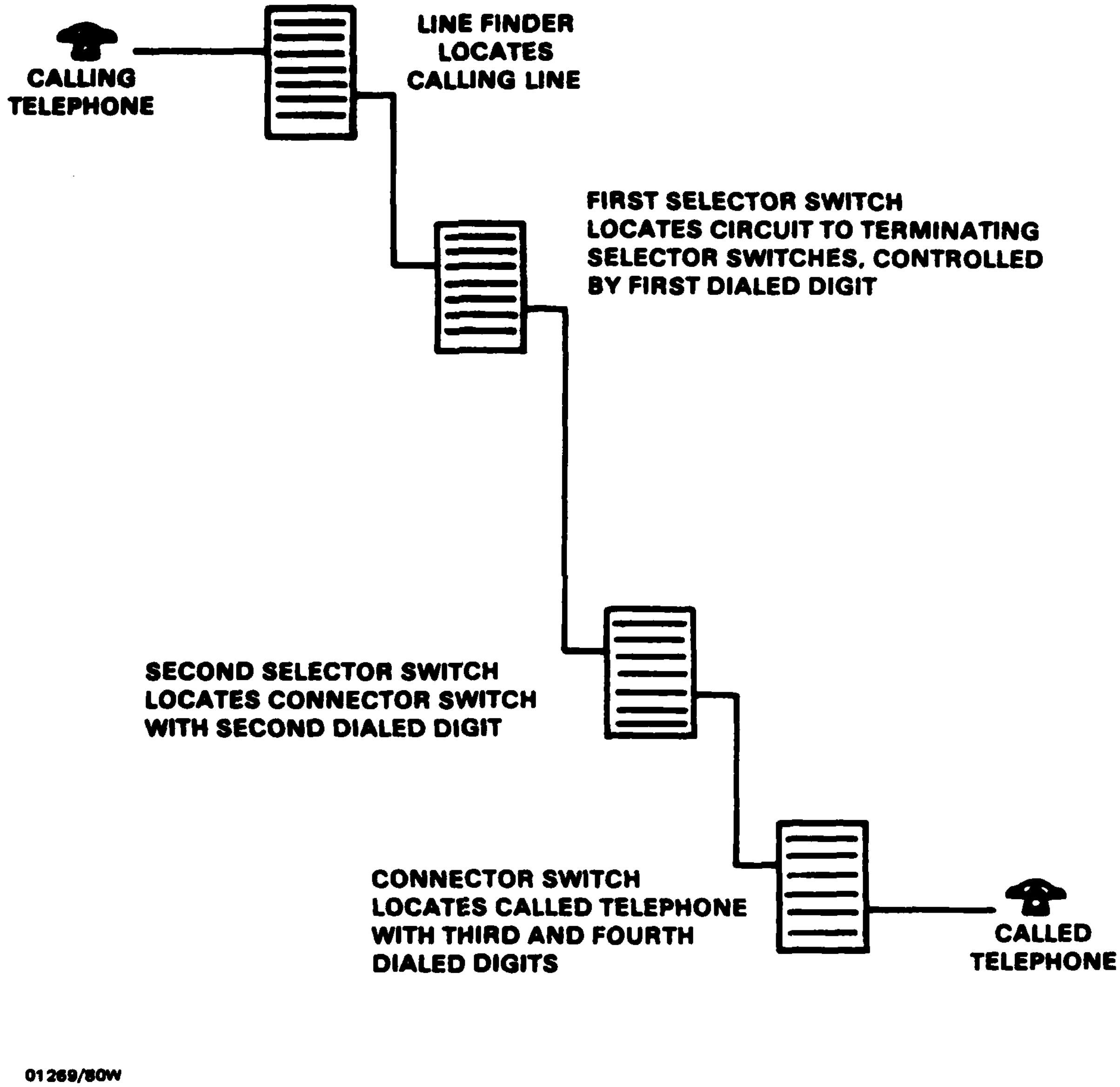


Figure 9. First Bell System electromechanical switching called the Step-by-Step.

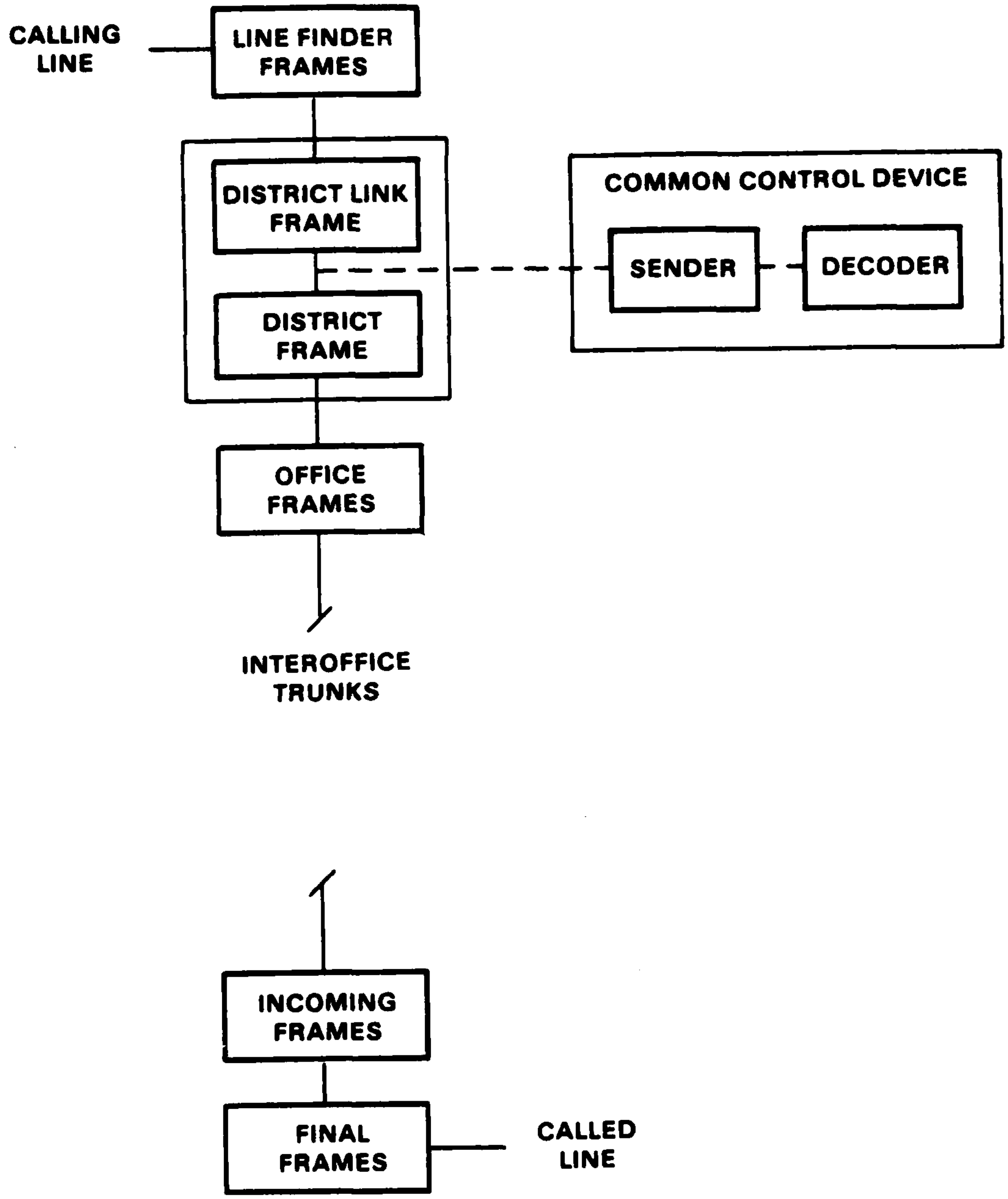


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Figure 10. Common, progressive control system called Panel Dial System.

operations of the switching network (consisting of district, office, incoming, and final frames). When the final connection to the called line is made, the sender disassociates and becomes available for other calls.

Like the Panel Dial System, the No. 1 Crossbar Switching System was developed for use in large metropolitan areas. It was the first of the crossbar systems; the last and most advanced being the No. 5 Crossbar System. The No. 1 Crossbar will be discussed as part of the detailed discussion involving the No. 5 Crossbar later in this Appendix.

## E.3 TOLL OFFICES

The first automatic toll office, a Step-by-Step, was installed in the early 1920's in Los Angeles. The success of this office led to other similar offices. All these offices, however, handled only short-haul toll business; long-haul intertoll dialing was not made possible until the early 1940's. The Step-by-Step Toll Systems are of 2-wire construction; most are directly controlled, and are located in class 4 offices.

The Crossbar Tandem System is an electromechanical sender-marker system (common control) with crossbar switches making up its switching network. Its original version (1941) was a replacement for certain Panel equipment being used as local tandems in Panel and No. 1 Crossbar areas. Later, functions including the ability to receive seven digits on a multifrequency basis were added. With this capability a local Crossbar Tandem could complete toll calls to all local offices in its area. Finally, this system began handling outgoing traffic (when the multifrequency inpulsing and outpulsing was expanded to 11 digits) and foreign area translation.

The largest of the Bell System's toll systems (until the No. 4 ESS) is the No. 4A Toll Crossbar. This system was intended for metropolitan areas and was designed to interface with all types of local and toll offices. The No. 4A Toll Crossbar was also designed to meet all of the nationwide toll dialing requirements. These requirements included foreign area translation, automatic alternate routing, and code digit manipulation (used in alternate routing).

The No. 4A Toll Crossbar is an electromechanical marker system with a 4-wire design (uses separate paths for each direction). As depicted

in Figure 11, incoming and outgoing trunk link frames, consisting almost entirely of crossbar switches, provide paths for connecting incoming trunks to outgoing trunks. Senders register destination codes pulsed from preceding offices and transmit the necessary information to the decoders. Decoders and translators determine the proper trunk group to the called office and also furnish senders with the information required to forward the call to the next office. Markers find an idle path through the switch frames, after which they operate the crossbar switches to establish the connection from the incoming to the outgoing trunk.

The translation function was originally performed by a card translator which contained a number of metal cards. Later, the electronic translator was introduced in the No. 4A System (a system so equipped is known as a No. 4A/ETS). The electronic translator consists of Stored Program Control (SPC) and peripheral circuits which are interfaces between the SPC and existing electromechanical equipment. Furthermore, an electrically alterable memory provides the mechanism with the capability to change translation information readily on a day-to-day basis.

## E.4 NO. 5 CROSSBAR

The No. 5 Crossbar is the most sophisticated electromechanical switching system developed by the Bell System. This system was originally developed for suburban residential areas and for smaller cities not requiring large multioffice telephone complexes. Considerations which influenced the design of the system included the expectation that a high percentage of cells would be completed to customers in the same office and the concept of direct distance dialing (DDD) by the customer.

The No. 5 Crossbar uses one switching network and a single marker to handle both originating and terminating traffic. Figure 12 illustrates the major components of this system, including the combined switching network (line-link and trunk-link frames) and the marker with its associated register and sender circuits. Connector circuits, also shown in the figure, connect the marker with other common control equipments, and to line-link and trunk-link frames.

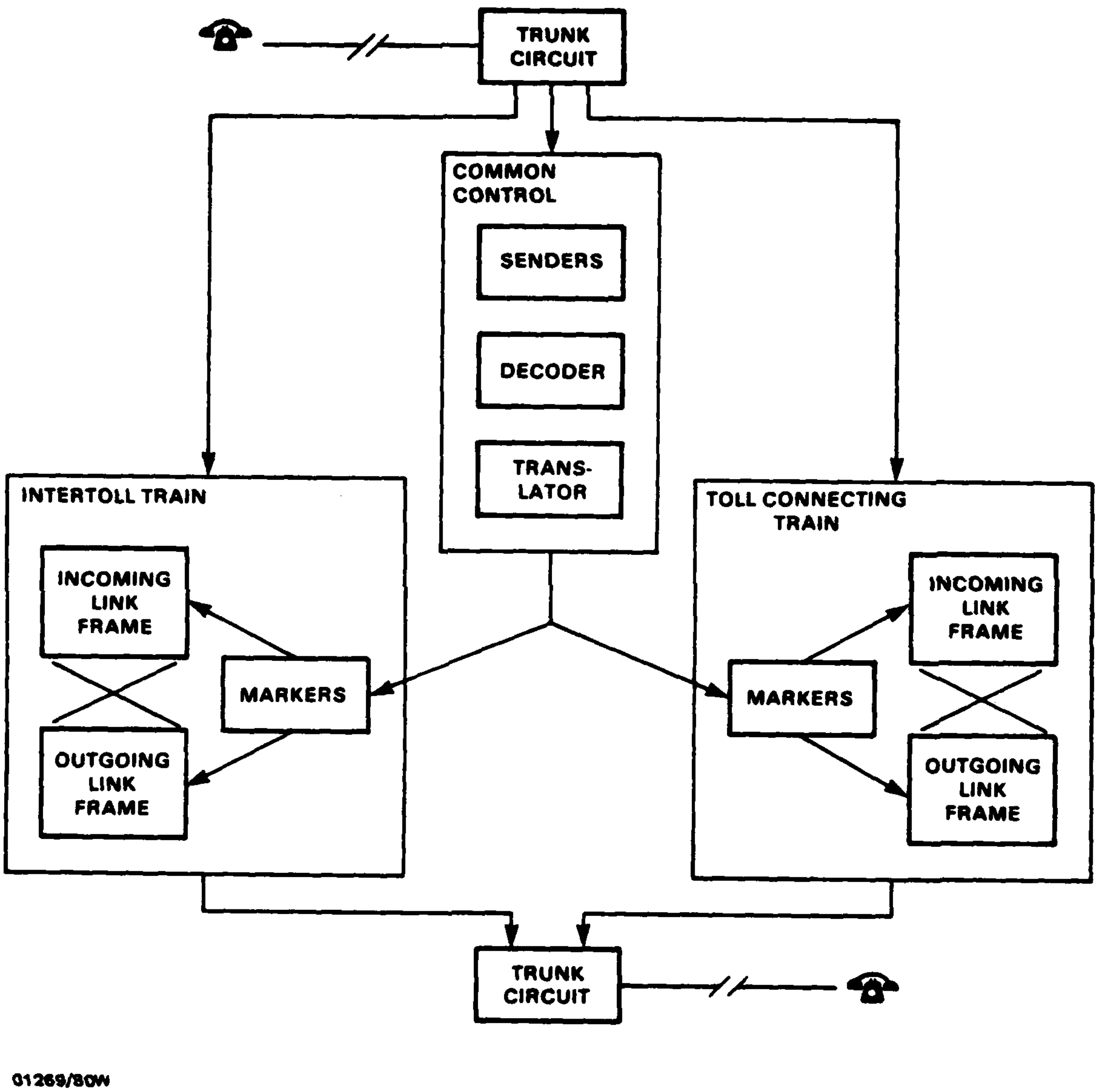


Figure 11. No. 4A Toll Crossbar.

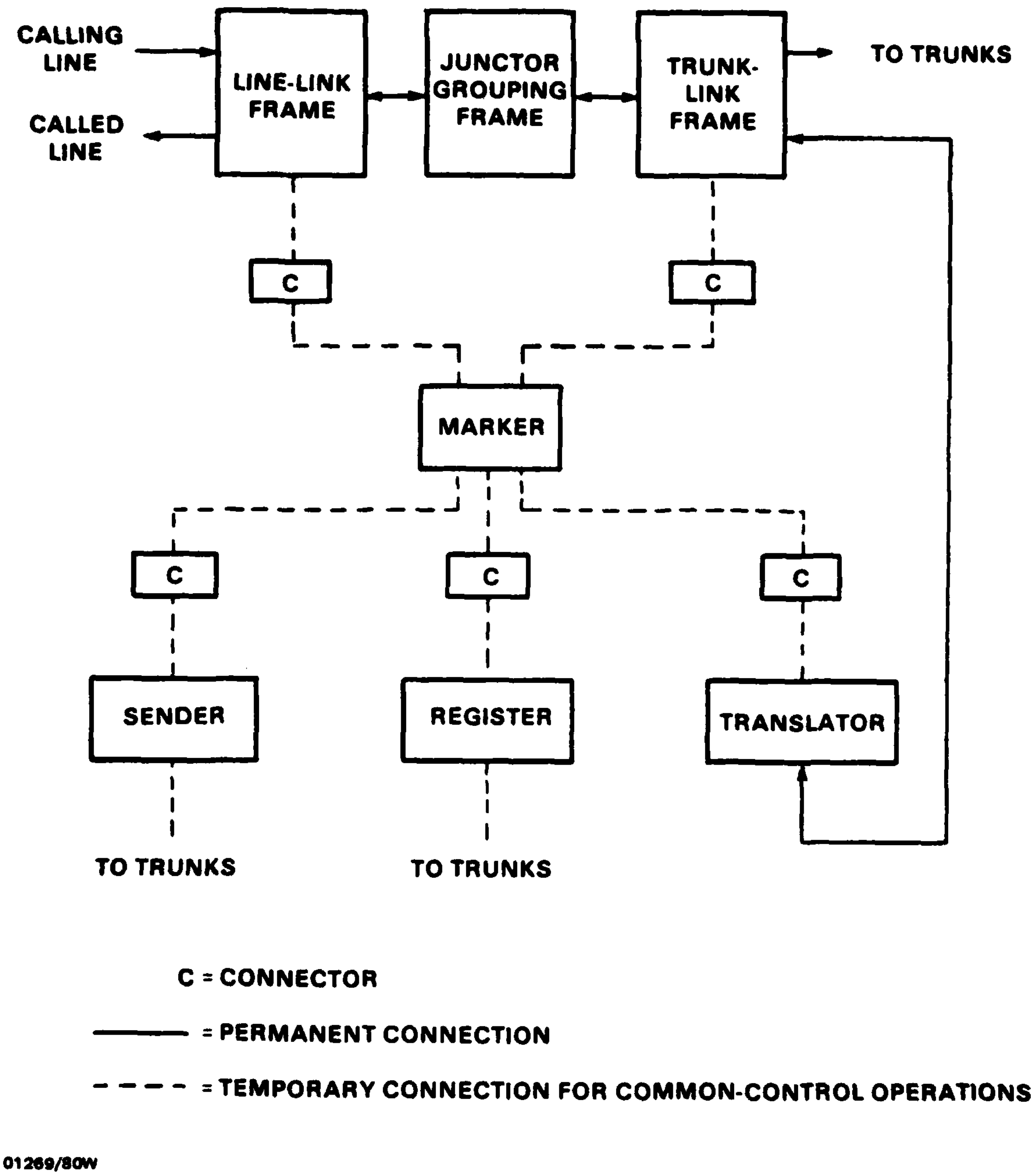


Figure 12. No. 5 Crossbar System.

The switching network consists of two basic switching frames: the line-link and trunk-link frames. Each frame is composed of two groups of 10 Crossbar Switches; line and junctor groups compose the line-link frame, and trunk and junctor groups compose the trunk-link frame. Connectors provide paths between the marker and common-control equipment, and between the marker and the frames.

The operational control of the No. 5 Crossbar switching system is centered in the marker circuit. The marker circuit establishes all connections within the central office including the paths between crossbar switch frames, idle trunks, and related equipment frames. It also determines whether the called line is idle or busy.

Each marker consists of two adjacent equipment frames, as illustrated in Figure 13. The first frame contains the translator and route relays which direct the call completing functions. The other frame handles common-control functions including controlling the line, trunk, and junction identification and selection operations. Additional frames common to as many as six markers contain the class-of-service relays and their cross-connection fields. Finally, with the major components of the No. 5 system reviewed, a synopsis of the processes involved in handling an interoffice local call can be given.

When a customer's handset is taken off-hook a connector circuit is activated. This circuit seizes an idle marker which proceeds to locate the calling line on the particular line-link frame and secure an idle originating register on a trunk-link frame. A path from the calling line terminals on the line-link frame, through the junctor group and trunk-link frames, to the originating sender is established by the marker before its release. The originating sender returns a dial tone to the calling customer and temporarily stores the dialed digits. An idle marker is seized when all seven digits have been received.

The incoming trunk in the distant office (previously the outgoing trunk in the calling office) is connected to the trunk-link and register-link frames. An incoming register circuit, which signals the outgoing sender to transmit the four digits, is selected when the incoming trunk is

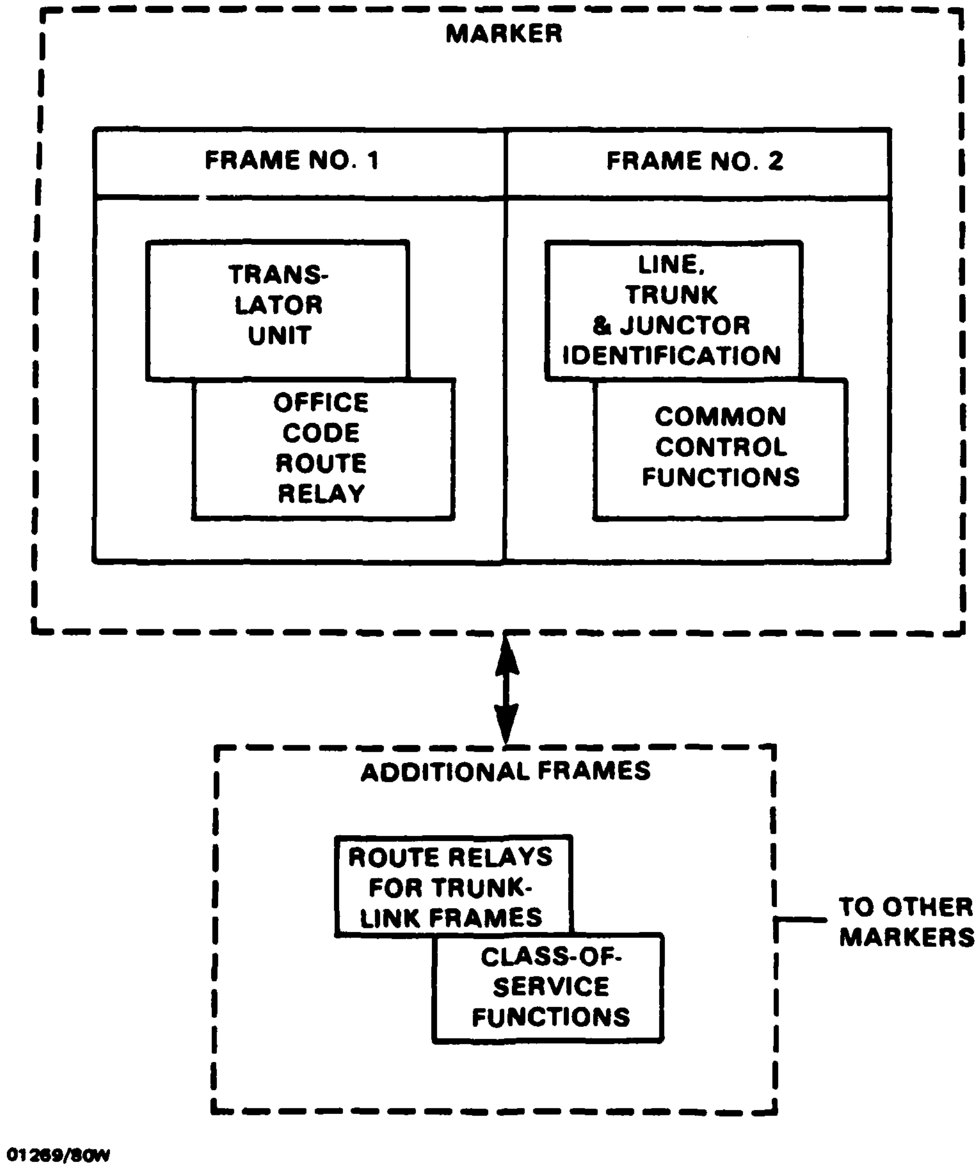


Figure 13. Marker frames for the No. 5 Crossbar.

seized. Next, the incoming register sends to a selected idle marker the four digits and other related data. This marker then connects to a number group frame in order to obtain the location of the called line number. Upon receiving this information the marker can connect to the indicated line-link frame and test the condition of the called line number. If the line is idle, the marker selects a path through the junctor group frame to connect the called line to the incoming trunk, and then releases. If, on the other hand, the line tests busy, the marker instructs the incoming trunk to send a busy signal to the calling line. The outgoing trunk supervises the call and controls the disconnection of the operated crosspoints when the calling party returns the handset to the on-hook position.

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## APPENDIX F
## ELECTRONIC SWITCHING SYSTEMS

### F.1 INTRODUCTION

In this appendix are described No. 1 through No. 4 Electronic Switching Systems (ESSs). This information follows the general concept information presented in Appendix D. No. 4 ESS is accorded special attention because of its potential in the development of a wartime switching router.

### F.2 NO. 1 ESS

The basic concepts of electronic telephone switching systems are exemplified in the No. 1 ESS. It was developed as a general-purpose switching system which would economically meet the growing demand for telephone services. The No. 1 ESS may be considered a high-speed processor which operates with a stored program of instructions and translation information. Its design was more flexible than any preceding system, it anticipated the needs for new services, and it avoided the high costs associated with modifying existing systems.

The No. 1 ESS uses a generic program to control the operations required for telephone service and maintenance of the system. The generic program is the same for all offices, includes all the functions necessary to cover office sizes from 2,000 to 65,000 lines, and includes a means for accommodating growth and changing traffic conditions. Data characterizing a particular office are found in translation tables in the program store.

The No. 1 ESS program responds promptly to signals and data submitted to it by customers and other switching systems. It also responds to trouble detection circuits designed into the hardware to ensure dependable operation. A hierarchy of program tasks was established so that the program could meet all the demands. Some tasks are performed on a strict schedule; others are delayed without affecting the customer.

The initial No. 1 ESS generic program provided basic local service for medium-sized metropolitan offices. Later a signal processor was added to increase its call-handling capacity for large metropolitan

offices. The No. 1 ESS demonstrated the success of the stored program and electronic digital processor concepts and served as the pioneer electronic system.

### F.3 NO. 2 ESS

The No. 1 ESS, designed for use in metropolitan areas where large numbers of lines with heavy traffic are served, is not economical for use in smaller localities and suburban areas. Consequently, the No. 2 ESS was designed by the Bell System, primarily to serve offices with 1,000 to 10,000 customer lines. Furthermore, the No. 2 ESS was designed to be largely unattended, and to be operated by remote control in most maintenance and test functions.

The service features of the No. 2 ESS are essentially the same as those provided by the No. 1 ESS. Moreover, it can provide four-party and eight-party service which is still needed in some suburban and rural areas. In case of large unanticipated growth, two No. 2 ESS offices can be combined into a dual central office. Data links would provide communication between the central office units of each office, and their switching networks would form a common network.

Many of the frames and apparatus developed for the No. 1 ESS are also utilized in the No. 2 ESS. The major components of the No. 2 ESS, as depicted in Figure 14, are arranged in a control complex consisting of two control entities. The control entity consists of a central processor frame, and one to four program store frames. The central processor frame provides the control functions.

The two control entities synchronize with each other. Normally, control unit 1 is in command of the call processing functions. A common maintenance and administration center allows control unit 2 to instantaneously take over operations in case of any failure. Each control unit connects to the switching network and other peripheral units over a peripheral bus system.

The smaller office size of the No. 2 ESS allows the extra processor time to do more processing per call. Thus, a lower start-up cost as compared with the No. 1 ESS is achieved with this system. Also, a simpler processing hierarchy than the No. 1 ESS leads to additional memory savings.

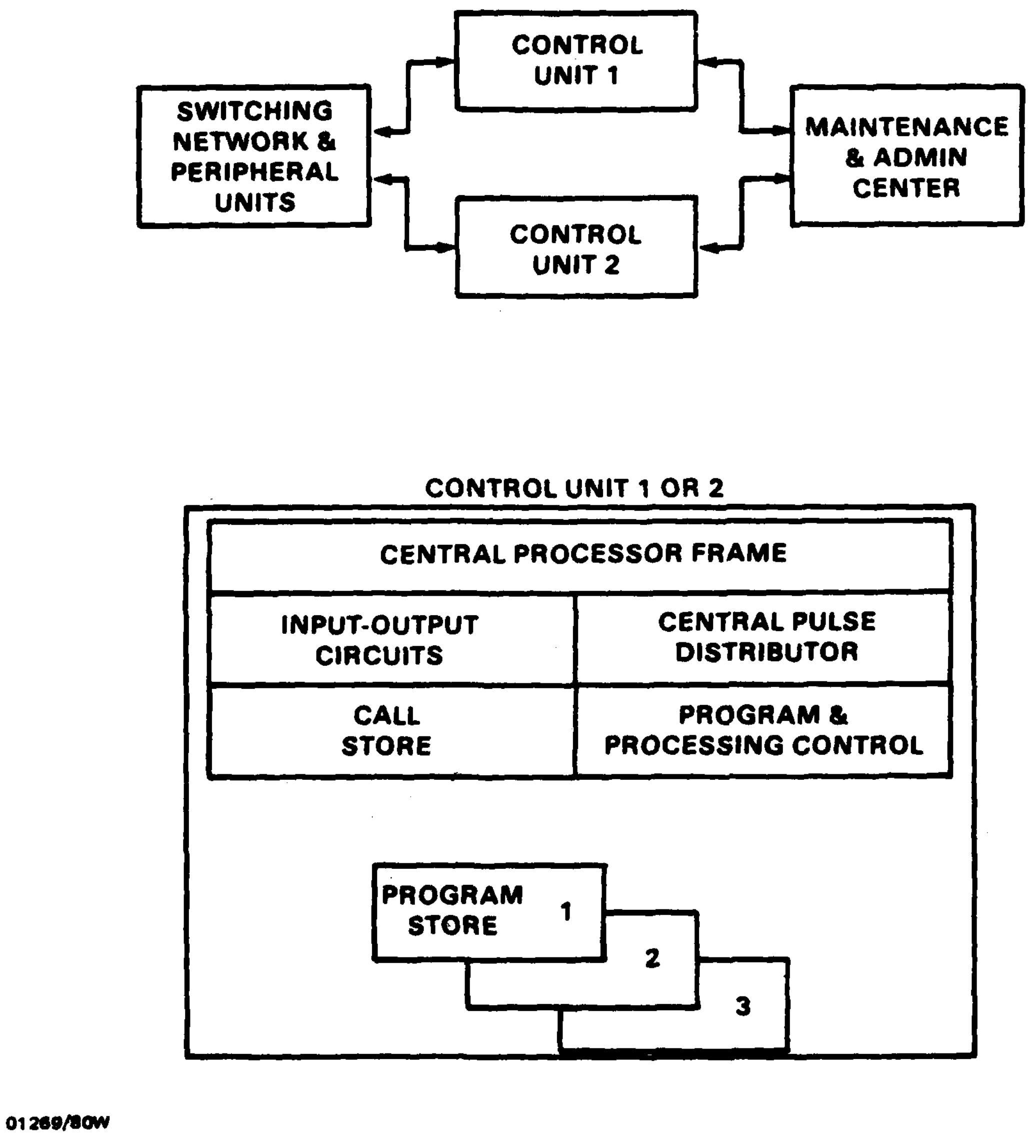


Figure 14. Major components and control unit of No. 2 ESS.

## F.4 NO. 3 ESS

Modern telephone service, available to urban and suburban areas through the No. 1 and No. 2 ESS, is provided to the rural community through the No. 3 ESS. This system is economically competitive with other alternatives (electromechanical systems) in a size range of up to a few thousand lines. Specific design objectives of the No. 3 ESS included the development of a small electronic switching machine which would allow short order-to-service intervals, involve less engineering effort by the telephone companies, be capable of unattended operation, and which would minimize the floor space and building requirements.

Unlike the previous electronic switching systems the No. 3 ESS uses a single frame design for both initial and growth units. This frame contains the necessary network and circuit elements to provide service for approximately 300 lines. Growth is accomplished by an addition to the frame, interconnecting it with the distributing and control frames.

The No. 3 ESS also uses a different type of processor than the No. 1 and No. 2 ESSs. This processor, the 3A processor, uses high-speed integrated circuits, making the speed of the system greater than required. This speed allows the autonomy of peripheral hardware to be minimized at the expense of processor real time. Furthermore, the 3A Processor has a semiconductor main store memory which serves as a combined program translation and call information store. Programs and translations are stored on cartridge tape chosen for low cost and good operational stability. The tape serves both to back up the main store (containing the critical programs) and as a low-cost source of programs whose usage is low.

## F.5 NO. 4 ESS

The No. 4 ESS is a high-capacity toll and tandem system designed to replace the No. 4A Crossbar which, until the No. 4 ESS, was the only system capable of providing full toll service. This radically new system contains a high-speed program-controlled processor, a digital time division switch, and terminal equipment to terminate both analog and digital trunks. Figure 15 illustrates the system in block form.

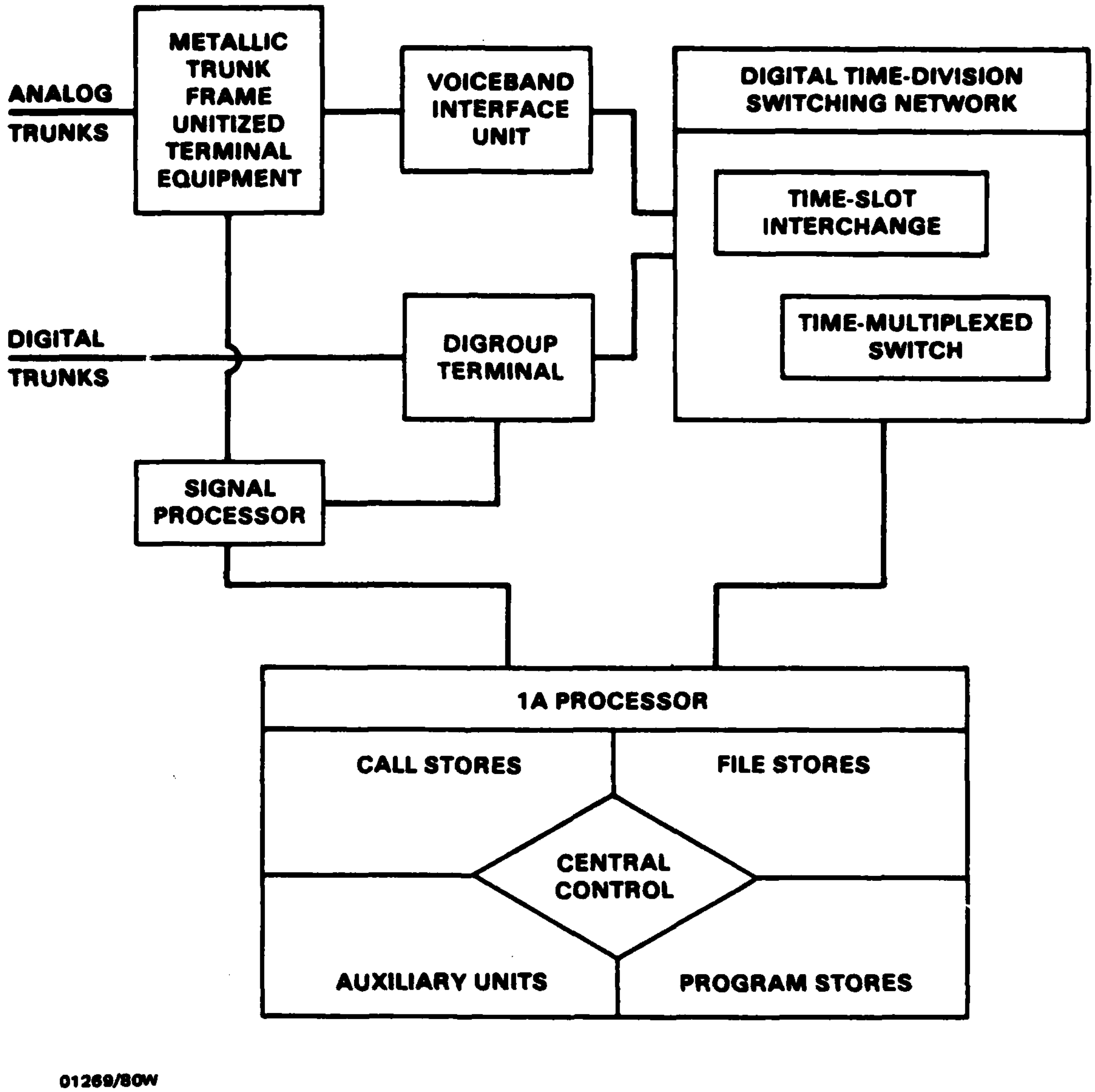


Figure 15. No. 4 ESS block diagram.

The No. 4 ESS was developed to cope with the tremendous increase in toll traffic. This growth is particularly noticeable in large metropolitan areas which were the first to require additional machines to handle traffic. This "metropolitan multimachine" problem will be alleviated by the No. 4 ESS since it can handle more than three times the traffic of the 4A Crossbar.

The No. 4 ESS, like other electronic switching systems, is controlled by a program store acting through a processor unit. The No. 4, however, employs a new type of processor, the 1A Processor, to control the switching machine. With advanced integrated circuits, this processor is four to eight times faster, is more dependable, and easier to maintain than other electronic processors. Central control directs other units of the processor complex as well as peripheral units to process calls and perform various system functions. Furthermore, the 1A Processor uses high-speed "writable" (electronically alterable) core memories in both program and call stores, and a high-capacity disk file having a lower access speed. Both contribute to the system's flexibility and economy.

In the Bell System, the No. 4 ESS is the first large machine to switch digital signals directly. In fact, the system can only switch digital signals, being a digital time-division switch based on a time-space-time configuration. In operation, it is essentially nonblocking because of its high call-handling capacity.

Most of the signals in a toll office today, however, are not digital, but analog. Before the analog signals can be processed by No. 4 ESS, they must be sampled, quantized, and coded in pulse-code modulation (PCM) form. These functions are performed by the voiceband interface unit. After switching by the time-division switching network, the signals must be changed back to analog form for further transmission over analog trunks.

Digital signals entering on digital trunks bypass the voiceband interface unit and are handled by the "digroup" (digital group) interface unit. This unit accepts digital signals and multiplexes them in the same PCM format as the voiceband interface unit. Beyond the interfaces, digital analog signals are in PCM format and can be switched as required in the

time-slot interchange (TSI) and time-multiplexed switch (TMS) complex, under the control of solid-state memories.

Signal processors are associated with the metallic-trunk frames, unitized terminal equipment, and the digroup interface unit (refer again to Figure 15). These processing units relieve the main 1A Processor of much of the repetitive signaling work. By assuming such tasks as receiving and transmitting dial pulses directly, and controlling multifrequency (MF) interoffice signaling, the main processor is able to handle much more traffic.

The increased speed and efficiency of the No. 4 ESS is also produced by common control interoffice signaling (CCIS) terminals, under controlled of the 1A Processor. Furthermore, these terminals allow the processor to communicate by data link directly with the controlling processors in other No. 4 ESS and 4A ETS (4A crossbar offices equipped with electronic translation) offices. The CCIS transfers signaling, network management, and other control information between offices.

A high degree of reliability is achieved in the No. 4 ESS through a completely duplicated switching network and path memory. The duplicate network keeps up-to-date on the status of all calls being switched and is ready to take over calls at any instant. This duplication also allows growth units such as additional trunks, transmission equipment, and switching equipment to be installed without inconveniencing the customer.

Standardization of floor plans for equipment, maintenance, and operating areas minimize the custom engineering required at installation. In addition, installation time is further reduced (when compared to an equivalent 4A Crossbar) by fewer frames and wires, precut connectorized cable, and more complete factory testing. A final advantage of the No. 4 ESS is floor space savings. Because of its modern integrated circuits and digital transmission facilities, approximately one-third the floor space is required for an equivalent 4A Crossbar system. This reduces the operating company's initial cost and thus makes the system more attractive.

The No. 4 ESS has been incorporated successfully in Bell System network. It has provided improved system operation and new service features at reduced cost in comparison to existing electromechanical systems. Improved hardware and software have made possible additional savings by reducing power and space requirements and has provided a substantial savings in equipment costs.

## APPENDIX G

## REFERENCES AND BIBLIOGRAPHY

The literature researched for this study and the personal interviews/meetings are listed below in seven broad catagories.

### G.1 COMMUNICATION NETWORKS AND TECHNOLOGY

(1) Holtzman, J. M., "Analysis of Dependence Effects in Telephone Trunking Networks", BSTJ, Vol. 50, No. 8, October 1971.

(2) Wilkinson, R. I., "Some Comparisons of Load and Loss Data with Current Teletraffic Theory", BSTJ, Vol. 50, No. 8, October 1971.

(3) Lin, P. M., et al., "Analysis of Circuit-Switched Networks Employing Orginating-Office Control with Spill Forward", IEEE TRANSACTIONS ON COMMUNICATIONS, Vol. COM-26, No. 6, June 1978.

(4) James, R. T. and Muench, P. E., "AT&T Facilities and Services", PROCEEDINGS OF THE IEEE, Vol. 60, No. 11, November 1972.

(5) Lee, Frank E., "Telephone Theory, Principles, and Practice", LEE'S abc OF THE TELEPHONE, Vol. 1, 1973.

(6) Lee, Frank E., "Station Installation and Maintenance", LEE's abc OF THE TELEPHONE, Vol. 2, 1976.

(7) Lee, Frank E., "Central Office Plant", LEE'S abc OF THE TELEPHONE, Vol. 3, 1976.

(8) Lee, Frank E., "Outside Plant: Engineering and Practice", LEE'S abc OF THE TELEPHONE, Vol. 4, 1977.

(9) Meyer, Bruce L., "Data Communications Practice", LEE'S abc OF THE TELEPHONE, Vol. 11, 1979.

(10) Piatowski, T. F., et al., "Inside IBM's System Network Architecture", EXECUTIVE GUIDE TO DATA COMMUNICATIONS, 2nd. Ed., McGraw-Hill Publications Co., 68-B.

(11) Kaiser, W. A., "New Services and their Introduction into Existing Networks", IEEE COMMUNICATIONS MAGAZINE, July 1979.

(12) Siegel, H. J., "Interconnection Networks for SIMD Machines", IEEE COMPUTER, Vol. 12, No. 6, July 1979.

(13) "Statistics of Communications Common Carriers", Federal Communications Commission, Year Ended December 31, 1977.

(14) Bell Telephone Laboratories, Incorporated, ENGINEERING AND OPERATIONS IN THE BELL SYSTEM, Indiana Publishing Center, Indianapolis, c. 1977.

(15) Kasson, James M., "The Rolm Computerized Branch Exchange: An Advanced Digital PBX", IEEE COMPUTER, Vol. 12, No. 6, July 1979.

(16) Masson, G. M., et al., "A Sampler of Circuit Switching Networks", IEEE COMPUTER, Vol. 12, No. 6, July 1979.

G.2 ROUTING/RECONFIGURATION TECHNOLOGY

(1) Thomas, R. E., "On Optimum Path Problems", NETWORKS, 6: 287-305, John Wiley & Sons, 1976.

(2) McQuillan, J. M., "Routing Algorithms for Computer Networks - A Survey", Bolt, Beranek and Newman, IEEE CONFERENCE RECORD, NTC 77, Vol. 2.

(3) Cook, T. J., et al., "Streamlining Network Management", BELL LABORATORIES RECORD, Vol. 56, No. 8, September 1978.

(4) Grandjean, C. H., "Call Routing Strategies in Telecommunications Networks", ELECTRICAL COMMUNICATION, Vol. 42, No. 3, 1967.

(5) Lin, P. M., et al., "Performance Analysis and Routing Plan Updating for Networks Employing Originating Office Control", School of Electrical Engineering, Purdue University, RADC Post-Doctoral Program.

(6) McQuillan, J. M., "Adaptive Routing Algorithms for Distributed Computer Networks", Bolt, Beranek and Newman, NTIS AD-781 467, May 1974.

(7) Frankel, T., "Tables for Traffic Management and Design", LEE'S abc OF THE TELEPHONE, 1976.

(8) Beckmann, Petr, ELEMENTARY QUEUING THEORY AND TELEPHONE TRAFFIC, LEE'S abc Publishers, 1968.

(9) Gallager, R. G., "A Minimum Delay Routing Algorithm Using Distributed Computation", IEEE TRANSACTIONS ON COMMUNICATIONS, Vol. COM-25, No. 1, January 1977.

(10) Ludwig, G. and R. Roy, "Saturation Routing Network Limits", PROCEEDINGS OF THE IEEE, Vol. 65, No. 9, September 1977.

(11) "Data Communications Using the Switched Telecommunications Network", BELL SYSTEM TECHNICAL REFERENCE, May 1971.

(12) Hovey, R. B., "Packet-Switched Networks Agree on Standard Interface", EXECUTIVE GUIDE TO DATA COMMUNICATIONS, 2nd. Ed., McGraw-Hill Publications Co., 68-B.

G.3 FUTURE TECHNOLOGY

(1) Steinberg, Ruth, "Technology Today and Tomorrow - An Interview with Ian M. Ross", BELL LABORATORIES RECORD, Vol. 56, No. 8, September 1978.

(2) Martin, James, FUTURE DEVELOPMENTS IN TELECOMMUNICATIONS, 2nd Edition, Prentice-Hall, 1977.

(3) The BDM Corporation, TECHNICAL CONCEPT PAPERS, Vol. II, BDM/W-79-042-TR, 15 February 1980.

G.4 ELECTRONIC SWITCHING SYSTEMS

(1) Carbaugh, D. H., et al., "No. 1 ESS Call Processing", BSTJ, Vol. 43, No. 5, September 1964.

(2) Spencer, A. E. and Vigilante, F. S., "No. 2 ESS: System Organization and Objectives", BSTJ, Vol. 48, No. 8, October 1969.

(3) Browne, T. E., et al., "No. 2 ESS: Control Unit System", BSTJ, Vol. 48, No. 8, October 1969.

(4) Digrindakis, J., et al., "No. 2 ESS: Peripheral System", BSTJ, Vol. 48, No. 8, October 1969.

(5) Andrews, R. J., et al., "No. 2 ESS: Service Features and Call Processing Plan", BSTJ, Vol. 48, No. 8, October 1969.

(6) Beuscher, H. J., et al., "No. 2 ESS: Administration and Maintenance Plan", BSTJ, Vol. 48, No. 8, October 1969.

(7) Lonnquist, C. W., et al., "No. 2 ESS: Apparatus and Equipment", BSTJ, Vol. 48, No. 8, October 1969.

(8) Barton, M. E., et al., "No. 2 ESS: Service Programs", BSTJ, Vol. 48, No. 8, October 1969.

(9) "Switching and PCM System Interfaces", Parts 1 & 2, Demodulator-GTE Lenkurt, Vol. 25, No. 7 and 8, 1976.

(10) Bruce, R. A., et al., "No. 4 ESS: Evolution of a Digital Switching System", IEEE TRANSACTIONS ON COMMUNICATIONS, Vol. COM-27, No. 7, July 1979.

(11) Johnson, G. D., "No. 4 ESS: Long Distance Switching for the Future", BELL LABORATORIES RECORD, Vol. 51, September 1973.

(12) "Introduction to Four Wire No. 1 Electronic Switching Systems", Student Package D97A, AT&T Long Lines.

(13) Thurber, K. J., "Circuit Switching Technology - A State-of-the-Art Survey", IEEE, 1978.

(14) Goeller, L. R., Jr., "Design Background for Telephone Switching", LEE'S abc OF THE TELEPHONE, Vol. 9, 1977.

(15) Fleming, Paul, Jr., "Principles of Switching", LEE'S abc OF THE TELEPHONE, Vol. 10, 1979.

(16) Ritchie, A. E., and L. S. Tuomenoksa, "No. 4 ESS-System Objectives and Organization", BSTJ, Vol. 56, No. 7, September 1977.

(17) Huttenhoff, J. H., et al., "No. 4 ESS-Peripheral System", BSTJ, Vol. 56, No. 7, September 1977.

(18) Boyle, J. F., et al., "No. 4 ESS-Transmission/Switching Interfaces and Toll Terminal Equipment", BSTJ, Vol. 56, No. 7, September 1977.

(19) Cieslak, T. J., et al., "No. 4 ESS-Software Organization and Basic Call Handling", BSTJ, Vol. 56, No. 7, September 1977.

(20) Abate, J. E., et al., "No. 4 ESS-The Switched Digital Network Plan", BSTJ, Vol. 56, No. 7, September 1977.

(21) Joel, A. E., Jr., "What is Telecommunications Circuit Switching?", PROCEEDINGS OF THE IEEE, Vol. 65, No. 9, September 1977.

(22) Joel, Amos E., Jr., "Circuit Switching: Unique Architecture and Applications", IEEE COMPUTER, Vol. 12, No. 6, June 1979.

(23) Hills, M. T. and S. Kano, PROGRAMMING ELECTRONIC SWITCHING SYSTEMS, Peter Peregrinus, Ltd., 1976.

(24) Hills, M.T., TELECOMMUNICATIONS SWITCHING PRINCIPLES, MIT Press, 1979.

G.5 TRANSMISSION SYSTEMS

(1) Kelcourse, F. C. and Herr, F. J., "L5 System: Overall Description and System Design", BSTJ, Vol. 53, NO. 10, December 1974.

(2) Bates, R. K. and Zorn, D. J., "L5 System: Signal Administration and Interconnection", BSTJ, Vol. 53, No. 10, December 1974.

(3) Nasell, I., et al., "The Transmission Performance of Bell System Intertoll Trunks", BSTJ, Vol. 47, No. 8, October 1968.

(4) Kessler, J. E., "The Transmission Performance of Bell System Toll Connecting Trunks", BSTJ, Vol. 50, No. 8, October 1971.

(5) Horn, Frank W., "Cable, Inside and Out", LEE'S abc OF THE TELEPHONE, Vol. 6, 1975.

(6) Nelson, K. C., "Understanding Station Carrier", LEE'S abc OF THE TELEPHONE, Vol. 6, 1975.

(7) Riley, E. W., and Acuna, V. E., "Understanding Transmission", LEE'S abc OF THE TELEPHONE, Vol. 7, 1976.

(8) Riley, E. W., and Acuna, V. E., "Transmission System", LEE'S abc OF THE TELEPHONE, Vol, 8, 1976.

(9) Bell Telphone Laboratories, TRANSMISSION SYSTEMS FOR COMMUNICATIONS, 1970.

G.6 GOVERNMENT INTERFACES

(1) Taylor, T. L., "The Role of Commercial Communications in National Emergency Preparedness", Naval Postgraduate School, NTIS AD-A031 818, September 1976.

(2) Linfield, R. F. and deHaas, T., "Interfacing the Automated Maritime Mobile Telephone System with the U.S. Public Switched Telephone Network", Department of Commerce NTIA 78-7, NTIS PB-286517, August 1978.

G.7 PERSONAL INTERVIEWS/MEETINGS

(1) Interview with Sam Wilson of Defense Civil Preparedness Agency (DCPA), August 8, 1979.

(2) Interview with Paul Fleming, Jr., Technical Director of U.S. Independent Telephone Association, September 5, 1979.

(3) Meeting with AT&T representatives (Marshall R. Snead, William E. Gordon, Edward J. Carlson, and Len Edwards), and Cpt. Michael A. King of Defense Nuclear Agency, September 26, 1979.

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ATTN: NIIS, Library

Headquarters Space Division
Air Force Systems Command
ATTN: SKF

DEPARTMENT OF THE AIR FORCE (Continued)

Commander-in-Chief
Pacific Air Forces
ATTN: Communications Electronics

Rome Air Development Center
Air Force Systems Command
ATTN: TSLD

Strategic Air Command
Department of the Air Force
ATTN: XPFS
ATTN: NRI-STINFO, Library

OTHER GOVERNMENT AGENCY

Federal Emergency Management Agency
ATTN: Plans & Operations (EO)

DEPARTMENT OF DEFENSE CONTRACTORS

American Telephone & Telegraph Co.
ATTN: M. Gray for W. Edwards

BDM Corp.
ATTN: L. Jacobs

Boeing Co.
ATTN: V. Jones
2 cy ATTN: H. Hendrickson

Computer Sciences Corp.
ATTN: H. Blank

ESL, Inc.
ATTN: J. Marshall

General Electric Company—TEMPO
ATTN: DASIAC

GTE Sylvania, Inc.
ATTN: M. Cross
ATTN: E. Motchok

Institute for Defense Analyses
ATTN: Classified Library

IRT Corp.
ATTN: R. Wheeler
ATTN: D. Swift
ATTN: L. Duncan

R & D Associates
ATTN: B. Gage
ATTN: W. Graham, Jr.
ATTN: R. Schaefer
ATTN: C. MacDonald
ATTN: P. Haas

R & D Associates
ATTN: J. Bombardt

SRI International
ATTN: A. Whitson
ATTN: G. Carpenter